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The Bulletin is published by The Institute of Physics for circulation to its members.

Notices to Members

Committee on Grants to Students

A Committee on Grants to Students has been set up by the Ministry of Education and the Scottish Education Department with the following terms of reference—" to consider the present system of awards from public funds to students attending first degree courses at universities and comparable courses at other institutions and to make recommendations."

It is expected that the Committee will consider the present " means test " applied to university grants. The chairman of the Committee is Sir Colin Anderson and one of its members is Dr. J. Topping (*Fellow*), a former Vice-President of the Institute who rejoins the Board from October 1.

International Convention on Transistors and Associated Semi-Conductor Devices

The Institution of Electrical Engineers is arranging a convention in London, to be held from May 25 to 29, 1959, and details may be obtained from the Institution. Dr. C. A. Hogarth (*Fellow*), Honorary Secretary of the Electronics Group of the Institute, is serving as a member of the organizing and technical program committees.

Contributions to the *Bulletin*

Although there is a large amount of material in hand for publication in the *Bulletin*, the average delay being several months at present, the Editor is always glad to consider contributions from members, in the form of either short articles or correspondence. Articles of less than 2,000 words would be particularly welcomed. They may be on any topic likely to be of wide interest among members and not so predominantly technical in nature that they would be more suitable for publication in one of the Institute's scientific journals. All articles submitted are subject to refereeing. Manuscripts should be addressed to the Editor of the *Bulletin*.

Radioactive Isotopes in Medicine*

By H. F. FREUNDLICH, M.A., F.Inst.P.

(*Physics Department, Bristol Royal Hospital*)

WORKING in the field concerned with the application of radioactive isotopes to medicine, one occasionally hears people expressing disappointment in the results achieved so far using this new technique. This is probably due to the fact that a number of people published papers in the late 1940's predicting spectacular new developments using radioactive isotopes. No doubt such revolutionary new discoveries have not materialized, at least not yet. In my opinion, however, a new technique should not be judged by a few spectacular successes which anyway would be largely due to the chance coincidence of a number of factors. A fair assessment can only be based on how far the applications of a new technique have spread and how much it has added to our scientific knowledge over a period of, say, twenty or fifty years.

With this in mind Table 1† shows how uses of radioactive isotope techniques have expanded over the first nine years since the first nuclear reactor became critical in Great Britain. Whereas the use of isotopes in hospitals has levelled off, in industry it is still rising. Tables 2 and 3 show the number of radioactive isotope samples dispensed for diagnostic and therapeutic purposes over the last three years at the United Bristol Hospitals. Closer investigation of these tables reveals a few points worth mentioning. The diagnostic tests can really be divided into three groups. To the first group belong those which have developed into standard clinical routine. An example of this are the tests using I^{131} for thyrotoxicosis. The second group are tests still in the development stage, but show a steady rise year by year and can safely be expected to become a recognized medical routine test in due course. The eye tumour malignancy test using P^{32} belongs to this class. Finally, there are tests of a more experimental nature. Radioactive isotopes are often used to provide certain data. Once this is achieved the tests are discontinued. The measurements of total exchangeable sodium using Na^{24} is an example of this type of work.

Before giving examples of uses of radioactive isotopes a few comments on instrumentation might be appropriate. When measuring small quantities of liquids containing traces of radioactive isotopes scintillation counters[1] are mostly used, provided the isotope is a γ-emitter (Fig. 1). Because of the greater efficiency the Geiger-Müller counter had to give way to the scintillation counter. But the

TABLE 1. HARWELL—ISOTOPE DIVISION. NUMBER OF ISOTOPES DESPATCHED

	1947	*1948*	*1949*	*1950*	*1951*	*1952*	*1953*	*1954*	*1955*	*1956*
United Kingdom										
Hospitals	5	49	904	1669	2801	3354	3834	2118	1871	2216
Universities ...	36	435	464	769	810	794	678	706	533	523
Industry	–	19	88	436	533	602	842	1021	1223	1261
Government Depts.	25	99	184	137	398	217	436	262	389	370
Others	4	13	11	25	34	36	49	76	431	432
AERE/RCC ...	65	764	1063	1273	1783	1846	2005	2052	2093	2680
U.K. Total ...	135	1379	2714	4309	6359	6849	7844	6136	6540	7482
Overseas										
Commonwealth ...	–	18	57	142	272	247	364	220	241	282
Others	–	17	223	1166	2124	3061	3951	2918	2457	3325
Overseas Total ...	–	35	280	1308	2396	3308	4315	3138	2698	3607
Grand Total ...	135	1414	2994	5617	8755	10157	12159	9274*	9238	11089

* Based on a lecture given to the South Western Branch of the Institute on December 13, 1957.

† I am greatly indebted to Mr. W. S. Eastwood, Isotope Division, Harwell, who kindly supplied this Table.

TABLE II. USE OF RADIOACTIVE ISOTOPES (DIAGNOSTIC)

	1954	*1955*	*1956*
1. Eye tumour malignancy test with P^{32}	7	39	42
2. Tracer test for thyroid metastases with I^{131} ...	13	11	12
3. *In vivo* tests of suspected thyroid carcinoma metastases with I^{131}	–	10	15
4. Biopsy counting for I^{131} uptake in secondaries ...	5	2	7
5. Thyrotoxicosis test with I^{131} (*a*) 4 hr. uptake	244	282	406
(*b*) P.B.I. uptake	255	336	450
6. Myxodema test using I^{131}	–	10	–
7. *In vivo* test of retro-sternal goitre with I^{131}	–	5	9
8. Red cell survival using Cr^{51}	–	24	9
9. Blood volume measurements using Cr^{51} ...	3	20	3
10. Anaemia studies in children with Fe^{59} ...	2	10	7
11. Total exchangeable No. using Na^{24}	19	24	1
12. Total exchangeable K using K^{42}	–	32	–
13. Radiocardiography with Na^{24}	–	–	45
14. Tissue clearance rate with Na^{24}	–	–	9
Total	309	523	609

Geiger-Müller counter is still used for pure β-emitters such as P^{32} or specialized applications such as the Veall crown of Geiger counters[2] which is extremely useful for routine measuring of radioactive tracers in urine or faeces (Fig. 2). For activities above 50 μC a specially designed ionization chamber[3] capable of accommodating vessels up to the size of Winchester bottles is regularly used for all routine measurements. (Fig. 3.)

Basically radioactive isotopes can be used in three different ways when applied to medical work :

1. purely as a research tool,
2. for diagnostic tests,
3. for therapeutic procedures.

The first examples to be described, namely, the use of I^{131} in the study of thyrotoxicosis illustrates all these three possibilities. Besides this it is undoubtedly the greatest success that radioactive isotopes have achieved so far in the medical field. It was in the middle thirties that it was discovered that all iodine taken orally is either absorbed by the thyroid gland or excreted in the urine. This statement somewhat over-simplifies the scientific facts, but can be considered adequate to describe the various functions I^{131} performed in the study and treatment of this disease. The experimental technique is shown in Fig. 4. A given amount of tracer I^{131}, usually 25 μC in a small bottle, is measured in front of a directional counting device, such as a directional scintillation counter, or a Geiger-Müller counter as shown in Fig. 4. Then the I^{131} is administered to the person to be investigated and the activity is measured over the thyroid gland at appropriate time intervals. In this way the uptake curves of the thyroid are

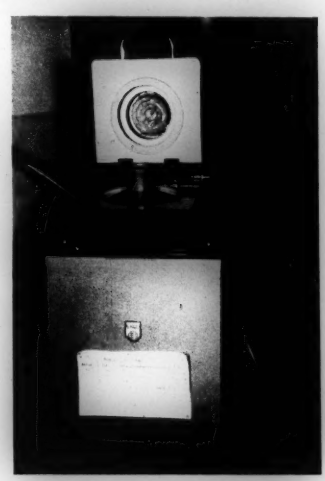

Fig. 1. *Annular scintillation counter.*

TABLE III. USE OF RADIOACTIVE ISOTOPES (THERAPEUTIC)

	1954	*1955*	*1956*
1. Treatment of thyrotoxicosis I^{131}	65	70	124
2. Treatment of carcinoma of the thyroid		4	6
3. Intracavity administration of colloidal Au^{198} ...	16	7	9
4. P^{32} β-ray applicators	7	18	31
5. Treatment of polycythemia vera	25	30	28
Total	113	129	198

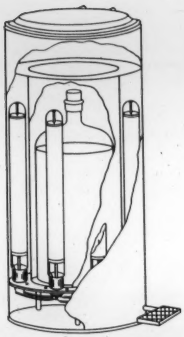

Fig. 2. *Arrangement of counter tubes and sample in pedal-operated bin.*

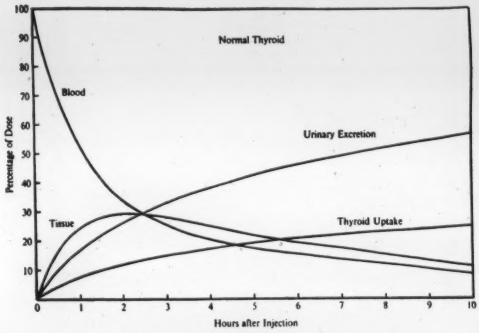

Fig. 5. *Distribution of iodine against time in a normal subject.*

Fig. 4. *Arrangement for measuring* I^{131} *uptake of the thyroid gland.*

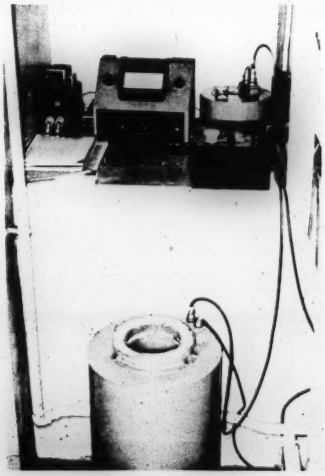

Fig. 3. *Concentric ionization chamber.*

obtained[4], as shown in Fig. 5. The urinary excretion of Fig. 5 could be most conveniently measured in a Veall crown of counters. The results of the same tests carried out on a patient with thyrotoxicosis are shown in Fig. 6. The thyroid uptake is greatly enhanced whereas the urinary excretion of I^{131} is correspondingly reduced. The basic facts which underly these results can be summarized as follows. The inorganic iodine which is selectively taken up by the thyroid gland is used by the gland for the synthesis of a hormone called thyroxin. This hormone is excreted from the gland into the blood stream and distributed all over the body where it performs certain functions. In the case of thryotoxicosis the thyroid gland produces this hormone at a rate well above normal and this, of course, requires a

correspondingly high absorption of iodine by the gland. The increased supply of thyroxin to the body produces symptoms such as loss of weight, nervousness or even serious overactivity of the heart. But similar symptoms can also occur in other diseases, such as in the case of certain abnormal heart conditions. The physician therefore welcomes this type of test, as it gives him a lead as to whether the symptoms he observes are primarily caused by over-activity of the thyroid gland or have to be traced to other causes. The clinical routine tests are similar to those just described, but instead of recording a complete uptake curve over several days, usually one measurement is performed either after four hours or twenty-four hours. As the statistics in Table 2 show, this type of test has now become an established routine.

This example has already illustrated how one piece of research has yielded a routine diagnostic test. In this case it also has provided a very successful method of treatment. In the days when radioactive isotopes were not available one of the standard treatments was to remove a certain portion of the thyroid gland by surgery. So by reducing this gland in size the production of thyroxin was reduced to a somewhat more normal level and the patient restored to health. The same effect can be achieved by partial destruction of the thyroid gland with the help of the β-radiation emitted by I^{131}. As experiments have clearly shown that iodine is only absorbed by the thyroid gland and by no other organ in the body, one can safely risk administering an adequate dose of I^{131} to produce a certain amount of cell destruction of the thyroid gland and to reduce thus the rate of synthesis of thyroxin. So we have here the case where a surgical operation has been replaced by the simple procedure of drinking a glass of water which contains a minute quantity of an impurity which even a chemist would find difficult to identify with his micro-analytical methods. This form of treatment too has now become well established as indicated in Table 3.

Another field where radioactive isotope methods have proved themselves extremely fruitful is haematology. The very complicated mechanism of iron metabolism is now fairly clearly understood, mainly due to investigations carried out with Fe^{59} just before and after the last war. More recently a problem which has puzzled physicians for about a hundred years has been beautifully clarified in its last stages of research with the help of radioactive cobalt. The problem referred to is that of pernicious anaemia. Anaemia in general is a class of diseases which is characterized by the lack of haemoglobin containing iron in the blood. This may be due to a reduced number of red blood cells or a reduced haemoglobin content in the red blood cells (R.B.C.). The first effect may be because loss of blood outstrips the producton of red blood cells, the second effect may be caused by a faulty production of the red blood cells in the bone marrow. A simple type of anaemia may be the result of lack of iron in the daily diet. This, of course, can be easily rectified by deliberately adding iron to one's diet. About 1855 Addison, a physician of Guy's Hospital, described a type of anaemia which could not be cured by adding iron to the diet, and among other symptoms, invariably proved fatal. Then in 1926 two American physicians Minot and Murphy[5] discovered that pernicious anaemia can be brought under control by regular injections of liver extract.

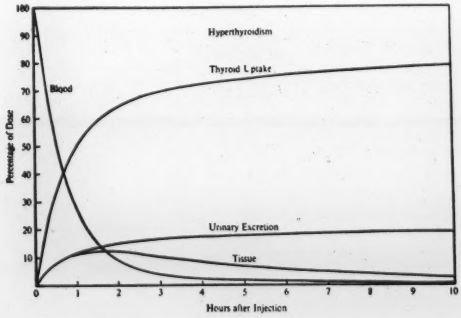

Fig. 6. *Distribution of iodine against time in a hyperthyroid patient.*

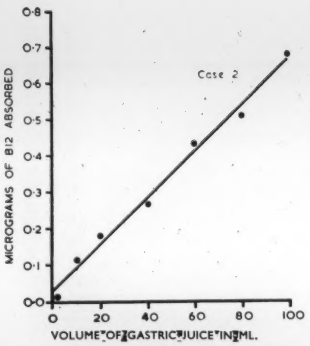

Fig. 7. *The amounts of ^{58}Co-labelled vitamin B_{12} absorbed by a patient with pernicious anaemia (case 2) when successive 0·8 g. doses of B_{12} were administered with different volumes of pooled gastric juice.*

The next step was brought about by the remarkable investigation of William B. Castle[6]. He evolved a theory which can be stated as follows :

Extrinsic factor + intrinsic factor required for R.B.C. production.

The extrinsic factor is provided by the diet and the intrinsic factor by the gastric juice. Castle could show that if the liver extract is given regularly by mouth together with a preparation made from a hog's stomach the symptoms of the disease disappeared and the patient's health was restored.

Lester Smith[7] of the Glaxo Laboratories succeeded in isolating the mysterious substance, so far called the extrinsic factor, from ox liver, and he was able to show that this substance was identical with vitamin B_{12}. He showed that when administered by injection it was highly potent in the treatment of pernicious anaemia. Also Callender and Lajtha[8] carried out experiments *in vitro* where they were able to prove that vitamin B_{12} together with gastric juice were instrumental in maturing pernicious anaemia cells into proper red blood cells. They also showed that B_{12} or gastric juice alone were ineffective. Castle's theory can therefore now be re-written :

Vitamin B_{12} + intrinsic factor required for R.B.C. production.

Vitamin B_{12} is a substance containing cobalt. This offered an excellent chance to follow up the metabolism of vitamin B_{12} in greater detail. Mollin and his associates at Hammersmith Hospital carried out a number of investigations using vitamin B_{12} tagged with Co^{58}. Fig. 7 clearly indicates that absorption of B_{12} in pernicious anaemia depends linearly on the amount of gastric juice administered simultaneously.[9] Fig. 8[10] gives us information about the fate of the B_{12} given by mouth in a normal subject. A large proportion is always excreted in the faeces (abdominal curve). The absorbed portion appears at first in the blood plasma and disappears from there to be stored in the liver (hepatic curve). This in particular confirms why the liver is such a rich source for extracting B_{12}. Fig. 9 are the results of similar tests carried out on a pernicious anaemia patient.[10] In Fig. 9 large quantities of B_{12} are excreted, no B_{12} appears in the plasma, also no activity appears over the liver after four days. There is only a short-lived activity which appears over the liver and which so far is still unexplained. But as soon as gastric juice is administered together with B_{12} (Fig. 10) these

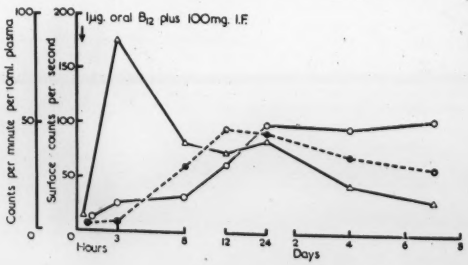

Fig. 8. *Abdominal (△ — △), plasma (● . . . ●) and hepatic (○ — ○) radioactivity after an oral dose of 1µg. of Co^{56}-B_{12} given to a control subject (case 3).*

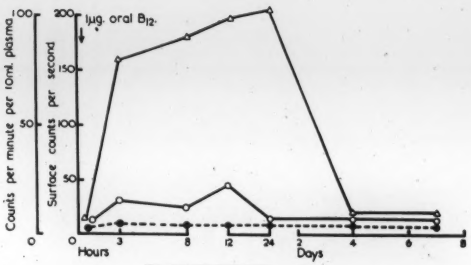

Fig. 9. *Abdominal* (△ — △), *plasma* (● . . . ●) *and hepatic* (○ — ○) *radioactivity after an oral dose of* 1μg. *of* Co^{56}-B_{12} *given to a pernicious anaemia subject.*

three curves take up shapes similar to those of a normal person, which is to say that the metabolism of vitamin B_{12} has returned to more normal ranges.[10]

These investigations, of course, suggest various procedures which could be adopted for clinical routine tests. For instance, after administering B_{12} without gastric juice the faeces of the patient would be regularly collected for a few days and its activity measured in a Veall Geiger crown. If 100 per cent of the given activity appears again in the faeces, then there can be no doubt that no vitamin B_{12} has been absorbed. An even simpler test would be to measure the activity over the liver with a directional counter for a few days after oral administration of B_{12}. Again if no activity appears over the liver, probably no B_{12} has been absorbed. The question of which test to adopt will undoubtedly be decided in the near future. We have just reached the stage where Co^{58}–B_{12} has become commercially available and quite a number of hospitals are planning to take up tests concerning pernicious anaemia.

Fig. 11. *Routine eye test.*

When discussing Table 2 it was pointed out that the eye tumour malignancy test is growing in popularity, and indeed there are strong reasons to believe that this is a diagnostic procedure which has come to stay. It has been known for a long time that when cell division takes place the cell produces an organic substance which is called

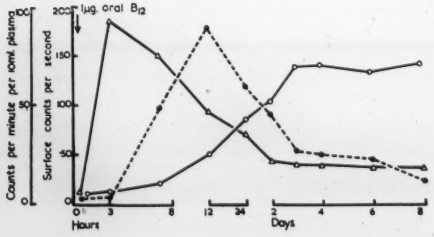

Fig. 10. *Abdominal* (△ — △), *plasma* (● . . . ●) *and hepatic* (○ — ○) *radioactivity in a patient with pernicious anaemia (case* 10) *given an oral dose of* 1 μg. *of* Co^{56}-B_{12}, *without (top curves) and with (bottom curves) intrinsic factor.*

desribonucleic acid (DNA) and which contains phosphorus. Therefore, wherever there is a high activity of cell division there is a high turnover of phosphorus. When dealing with abnormal growth the surgeon or radiotherapist distinguishes between malignant and non-malignant tumours. The first type are tumours which grow rapidly, are highly destructive and are likely to start secondary tumours in other parts of the body. These tumours always show a high turnover of phosphorus because of their rapid growth. Non-malignant tumours, on the other hand, are slow growing and do not display this dangerous ability of starting up secondary tumours. Whenever a tumour growth is investigated one of the first tests carried out by a pathologist is to look through a microscope at a small sample of the tumour. From the type of cells observed the pathologist can usually decide whether the growth is malignant or not. However, this test is impossible to carry out on an eye tumour, as no sample could be obtained without destroying the eye.

Pathological cell tests, as just described, carried out on tumour samples after the affected eye had been removed have shown that in 10–12 per cent of cases the operation was unnecessary, as the growth proved afterwards to be non-malignant.

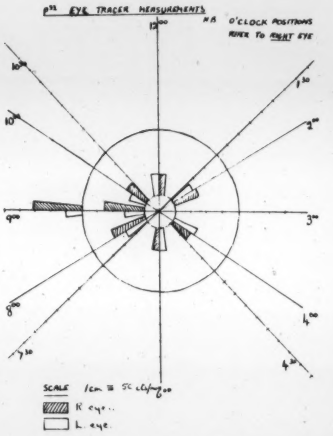

Fig. 13. *Test results obtained from malignant eye tumour.*

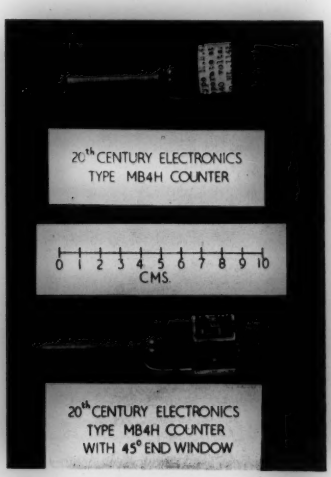
20th CENTURY ELECTRONICS
TYPE MB4H COUNTER
0 1 2 3 4 5 6 7 8 9 10
CMS.
20th CENTURY ELECTRONICS
TYPE MB4H COUNTER
WITH 45° END WINDOW

Fig. 12. *G.M. counters used for eye tests.*

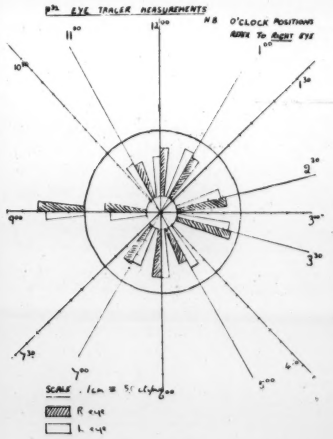

Fig. 14. *Test results obtained from a non-malignant eye-tumour.*

By giving radioactive P^{32} to patients with eye tumours and comparing the activity of the affected eye with the normal eye, a test has been provided to decide before an operation is performed whether the tumour is malignant or not.[11] The test is carried out with a particularly designed small Geiger-Müller counter (Figs. 11 and 12). The activity is measured right round the eye and usually the activity directly over the tumour, when malignant, is about twice that obtained over the corresponding spot of the normal eye. This is illustrated in Fig. 13. Close on a hundred tests of this type have been carried out at the Bristol Centre, and as expected in about 10–12 per cent of the cases seen the operation of the affected eye has been postponed because there was no significant difference in activity between the two eyes. Fig. 14 shows the result of such a test. Of course, patients with suspected non-malignant tumours are seen from time to time to make sure that there is no further growth. It is still too early to assess whether these tests have given in each case the right answer. Whereas in nearly all cases where the operation was performed, the malignancy was confirmed, non-malignancy can only be accepted as proven if the tumour remains static over at least five years.

In conclusion I hope that these examples will have convinced you that radioactive isotope techniques are a powerful tool in medical research as well as in clinical routine. The statistics I mentioned at the beginning have revealed that already a considerable ground has been covered, and given more time and hard work I feel confident these radioactive isotope techniques will prove to be one of the most fruitful contributions physics has ever made to medicine.

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Reviews of Books

THREE STEPS TO VICTORY

By Sir Robert Watson-Watt

London : Odhams Press Ltd. Pp. vi + 474. Price 30s.

This book is long and detailed and it is rambling and diverse, but I can assure all those who worked in the field of radar, that it is well worth their attention.

The very diversity of the book will result in some of its messages remaining obscure to the more casual reader, but most of the problems which are faced in introducing some new concept of applied science into everyday use are to be found within its pages. For example, in the early stages of development of some new device, operational experience of quickly produced experimental models is often more valuable than endless laboratory research. In wartime a few such equipments used operationally may be of far more value than a polished production run later. Yet these obvious facts are overlooked to a surprising degree unless there is close contact with the ultimate user.

Again, when some new concept like radar becomes apparent, most of the possible applications will become clear within a space of a few months and it becomes absolutely essential to select a priority for their development. Watson-Watt talks in his book of the " ice-box " into which many new ideas and many of the possible applications of radar had to be put, so that the more promising or immediately useful could see the light of day within a reasonable time.

Another important concept which Watson-Watt brings up is that in the early days of development of a new applied science, it is absolutely essential for those who are developing it to be in touch with those who are considering the strategy of its use. In this way, and in this way only, will it be possible to make any reasonable use of the concept on a short time scale. As the applications of a new device become more and more widely appreciated, the need for this contact diminishes and it may well be satisfactory for a research organization to be in contact only with those who are concerned with tactical use. An establishment, which has existed for some considerable time, will only have this latter type of contact, and, as a result of the creation of managerial layers elsewhere, it will be extremely difficult to develop direct contact between user and the creative younger scientist. There is a great deal to be said for forming new establishments when some new and important concept breaks upon the scene. Such an establishment must ultimately die in its original form and change into one of more orthodox pattern. Examples will no doubt occur to the reader.

Another point to which the author refers is that in the early stages, when a few hand-made equipments are required, it may be more effective if the scheme is handled as a piece of experimental applied science rather than as an engineering project. In the later stages, however, and especially when a reasonable quality and economy in production are needed, it is clear that the engineering aspects will assume the greater importance.

The author raises also the question of who should support topical research at a time when no military conflict exists. Should it be the Services ? Should it be a body such as the Department of Scientific and Industrial Research ? He refers also to the lack of gratitude of sections of western society towards people in the scientific and technological and engineering professions, but especially the former.

Many of the questions the author poses are left unanswered, but their discussion in the context of radar leaves much food for thought. The extreme casualness of the occurrence of key developments is one of the most lasting impressions I have retained from reading this book.

I hope this late review may possibly encourage some of those who neglected the book when it was first published, to obtain a copy and read it now.

J. V. DUNWORTH.

APPLIED MATHEMATICS FOR ENGINEERS AND PHYSICISTS

By L. A. Pipes

London : McGraw-Hill Publishing Co. Pp. xi + 723. Price 68s. Second Edition.

Professor Pipes could hardly have chosen a better time for the appearance of this second edition of his book in Great Britain. The urge to produce more and more engineers and physicists carries with it the need to equip them with a knowledge of mathematical techniques which can be used in solving modern technical problems.

In this book we have a wonderfully clear exposition of many such techniques by one who is admirably qualified to have written it. The author has not only a long experience of teaching mathematics to applied scientists in America but is also a practitioner in his own right. He has published many papers on a wide range of problems in applied mathematics and engineering. In the reviewer's opinion, this book would form an excellent guide both for the planning and teaching of mathematics in the sandwich courses leading to the new Diploma in Technology. The author uses the term " Applied Mathematics" in what is rapidly becoming the accepted sense of mathematics readily applicable to the solution of practical problems as distinct from the older and more restricted meaning of " Mechanics."

The first three chapters of the book are concerned respectively with infinite series, complex numbers and Fourier series and integrals. The fourth chapter deals fairly thoroughly with linear algebraic equations, determinants and matrices. All but the more mathematically-minded engineering students will find this a heavy chapter. There are useful references to modern numerical techniques for handling large numbers of equations but curiously no mention of relaxation methods. Perhaps the author is among those who feel that such methods are on the decline. The chapter on the solution of transcendental and polynomial equations is relatively short and straightforward. Chapter 6 presents three methods of solving linear differential equations with constant coefficients ; the use of the operator **D**, the method of undetermined coefficients and the Laplace transform. It is worth noting that the first method is not made use of elsewhere in the book which raises the question as to whether it might have been removed altogether in favour of transform methods. The following three chapters describe the applications of such differential equations and their solutions to oscillating electrical circuits, vibrating mechanical systems and the theory of structures. Under the latter heading is included a short but illuminating account of Rayleigh's method of calculating natural frequencies which brings out so well its physical significance. Chapter 10 is an attractive introduction to finite differences and operators, though it seems a pity that the author did not go just that little bit further and indicate how integration formulae could be used in the numerical solution of differential equations. A strong case is made, based on their practical application, for the importance of difference equations. Chapter 11 on partial differentiation includes an introduction to the calculus of variations and to Lagrange's equations. The following three chapters present some standard mathematical functions and their chief properties : the functions are the gamma, beta and error functions and those of Bessel and Legendre. In the chapter on vector analysis, there is also a very brief introduction to tensor analysis which is largely a collection of definitions. For the practical usefulness of tensors the reader is directed to standard references. Three chapters are devoted to the solution, by separation of the variables, of partial differential equations, namely the wave equation, the Laplace equation and the equation of heat conduction. Solutions of the latter equation in terms of error functions are hinted at but the reviewer would like to see them given more prominence as they are of considerable practical importance. Here also there is no mention of numerical methods for solving partial differential equations, though perhaps one or two references is all that can be expected. The chapter dealing with the theory of the complex variable is followed by applications to the solution of two-dimensional potential problems. Transform methods receive a fuller treatment in Chapter 21 than is usual in this kind of book and applications to integral equations and the summation series are included. The final chapter is concerned with modern developments in the techniques of solving non-linear differential equations relating to oscillatory systems.

This second edition contains many new and expanded sections dealing with developments in techniques which have occurred since the first edition appeared twelve years ago. There are numerous examples for the reader to attempt and copious references to guide his further reading. A few misprints were spotted which are not serious though they may upset the student meeting the subject for the first time. The book is, however, very well produced and deserves to be widely used by students, teachers and practising applied scientists.

J. CRANK.

CONCEPTS OF FORCE

By Max Jammer

London : Oxford University Press. Pp. ix + 269. Price 45s.

In this book Professor Jammer has performed a greater service to scholarship than providing a mere chronological description of the growth of the concept of force. He has demonstrated how men's minds have worked on this problem, and

wrestled with its subtleties. In the event, not only has *homo sapiens* acted upon the abstraction of force, but this abstraction has itself acted upon him. Yet when all is said and done, it remains true that the bodily sensation of effort is always present as the natural man's idea of force. In a more sophisticated context, as the author says, the preoccupation of physics with technological developments has had lamentable effects in relegating to a quite minor role a factor of supreme consequence in the history of the human intellect.

To the Judaic mind, there was an urge to reconcile force with righteousness and morality; to the Greek the test was to find a balance between force and destiny. We have moved far indeed from both these tenets, but the lessons they teach are not trivial. The first is, in essence, catastrophic and speaks in terms of crisis (judgment) ; the latter—much more gentle—seeks for compromise, at the cost of no small element of teleology. To-day, we are not so frightened of " ends " as opposed to " means " as we used to be, a result perhaps of our twentieth-century concern with biophysics as a live subject. Directiveness has become interesting to a degree never envisaged at the close of last century.

For a volume so well documented it is a little surprising to find no reference to the treatment by K. O. Müller (continued by Donaldson) in his *Literature of Ancient Greece* (1858), wherein the distinction between Heraclitus and Anaxagoras is discussed in masterly fashion ; nor yet again Cleve's *Philosophy of Anaxagoras* (1949) with its crucial insight into " nous " and " his " cosmological influence. But in general Professor Jammer's pages are models of a scholar's care in dealing with his original sources ; in the present case of course they are basic for his theme. It is for this meticulus accuracy that *Concepts of Force* is likely to be so valuable, and a timely reminder to present-day authors to recollect their history.

The gradual emergence of a truly scientific grasp of the character of force is followed in great detail through Kepler, Galileo, Descartes, Newton, Leibnitz, Boscovitch, and the Cambridge Neo-Platonists, to the extreme position assumed by Mach and the Vienna Circle. The latter claimed in effect that any concept which could not be measured was meaningless.

In contemporary physics, as Professor Jammer observes, force is akin to the middle term of the traditional syllogism in that it drops out in the conclusion when, for example, a body A is surrounded by a constellation B, C, D, etc., as it moves in its trajectory.

It is a pity that time presses so heavily upon our curricula ; an hour or two spent with this first-class book should enliven our struggles no end with the parallelogram of forces.

F. I. G. Rawlins.

THREE DIMENSIONAL DYNAMICS

By C. E. Easthope

London : Butterworth's Scientific Publications. Pp. vi + 277. Price 42s.

Dr. Easthope's book is based on lectures given in the University College of Wales, Aberystwyth, and is intended for honours students in mathematics in their second and third years. It covers much that is included in A. S. Ramsey's *Dynamics*, Volume II, and Lamb's *Higher Mechanics*, but the treatment is largely vectorial throughout. It is not as thorough-going as Milne's *Vectorial Mechanics* ; tensors are not included, and Lagrange's equations and Hamiltonians are omitted. Also, the theory of moments of inertia and Euler's equations have had to be treated in a traditional way. This is in some ways unfortunate but one appreciates the author's reasons for his selections ; students generally find vector methods difficult enough and, as he says, " the properties of tensors and the laws of tensor algebra are, on the whole more difficult to master than those of vectors . . . One has, therefore, to strike a balance between the mastering of a technique and that of the subject itself." It is to be hoped, however, that at some stage the students will tackle tensors and some of their applications in mechanics and in theoretical physics. This book should enable students to use vector methods with confidence and to gain a firm knowledge of three-dimensional mechanics. Honours students, however, will need to work more examples than the half-dozen or so included at the end of each chapter.

J. Topping.

THE HISTORY AND DEVELOPMENT OF LIGHT CARS

By C. F. Caunter

London : Her Majesty's Stationery Office. Pp. viii + 120. Price 8s. 6d.

In a mere 110 pages this book traces the development of motor vehicles of under 1,500 c.c. engine capacity from the earliest days of motoring to the present time. The treatment is, however, detailed, searching and indeed encyclopaedic. It will be a valuable source of reference to those having an interest in motoring history.

D. T. R. Dighton.

Branch and Group News

London and Home Counties Branch : Visit to London Airport

The Spring visit of the Branch to London Airport was held on April 29. The visit was over-subscribed and had to be limited to fifty members. Those fortunate enough to be able to attend spent a most enjoyable and instructive afternoon in magnificent summer weather.

The party had the opportunity of watching the Central Air Traffic Control room in action and going on to the roof of the Control Tower Building from where a clear view of the air traffic was obtained. After a short talk on the airport communication and control systems we visited the message control centre and air/ground conversation recording rooms. One of the most remarkable pieces of equipment was the new 8mm short range radar installation which can pick out every detail of the airfield and all personnel, vehicles and aircraft on it in any weather. Finally we were shown round the extensive new meteorological forecasting facilities after a most enlightening description of this service, which is provided for every aircraft leaving the airport.

The party was greatly indebted to the guides who willingly answered numerous questions put to them—a clear indication of the great interest aroused. The visit was concluded with tea at one of the airport restaurants.

T. W. Lindop.

London and Home Counties Branch : Summer Meeting

A most interesting and enjoyable time was had by those members, and their guests, who visited Marchwood Power Station and made a short tour of the New Forest on Saturday, June 7.

Mr. A. D. Matthews, Superintendent of the Station, gave the party a warm welcome and described the history, construction and design of the project, pointing out the advantages of the Marchwood site. Originally the station was built to use either coal or oil fuel, and there is a large deep-water coaling berth and handling plant. However, the establishment of the Esso Fawley Refinery about seven miles away down the river Test has meant that since the station went into production in November, 1955, it has been oil fired. This very high viscosity, low grade fuel oil has to be steam-heated at Fawley in order to pump it into tankers of 5,000 tons capacity, which then come up river to Marchwood and pump the oil whilst it is still warm into heated storage tanks. The five 60,000 kW. generator sets now in operation require about 11,000 tons of oil a week. It is expected that three more sets, making a total of eight, will be in operation by the middle of 1959.

Mrs. A. D. Matthews, Professor A. M. Taylor, Miss S. M. Matthews, Mr. A. D. Matthews and Mr. D. T. R. Dighton.

The party was divided into groups, and the members saw all they wished to, and had all their questions answered by their guides. After a very satisfying lunch and expressing their thanks to Mr. Matthews, the party went by bus to Beaulieu.

Here the ruins of Beaulieu Abbey were inspected, the veteran motor car museum visited and a tour made of the Palace House. This was followed by a Cream Tea in the Montagu Arms.

The coach then took the party to see Buckler's Hard, where once the oak battleships of England were built. Now it is a favourite resort for yachtsmen and is a very attractive spot. The tour of the New Forest was completed by a ride round Brockenhurst and Lyndhurst.

Altogether it was a full, but most interesting, enjoyable, and well-organized day.

T. H. Tyler.

Scottish Branch : Summer Meeting

The Scottish Branch held their Summer Meeting at the Experimental Reactor Establishment at Dounreay on Saturday, June 21, at the invitation of the Director, Dr. R. Hurst.

Over thirty physicists from Glasgow, Edinburgh, Aberdeen and Dundee, travelled the 300 miles to Dounreay through the Highland scenery. Very fine accommodation had been reserved for members at Ormlie Lodge in Thurso, and the following morning the party gathered at the gates of the establishment to be received by Mr. C. R. Tottle.

Mr. Tottle expressed his interest and delight in the gathering—the furthest north of any meeting of The Institute of Physics—and then gave a short but complete summary of the build-up of the Dounreay establishment and the aims and possibilities for the future.

The party then divided into small groups and were escorted to different parts of the establishment by guides—senior members of the establishment—who most helpfully explained all detailed points.

After lunch The Institute of Physics gave their contribution to the meeting and a lecture on " Radiation and Life " was given by Dr. G. A. P. Wyllie (Lecturer in Natural Philosophy, University of Glasgow), which was received with very great interest by those present.

At the end of the lecture Dr. Lenihan, who had been chairman for Dr. Wyllie's lecture, thanked Mr. Tottle and his staff on behalf of all the visitors and presented him with a silver cigarette box from the members to mark the visit and express their appreciation. The visitors were indeed most appreciative of the real welcome extended, and the interest taken by the whole staff at Dounreay.

During the evening a joint meeting was held with the Thurso Philosophical Society, and a combined lecture was given by Seumas McNeill (Lecturer in Natural Philosophy, University of Glasgow ; Principal of the College of Piping) and Dr. J. M. A. Lenihan (Physicist to the Western

Mr. B. J. Owen, Mr. C. R. Tottle, Dr. A. G. P. Wyllie, Dr. J. M. A. Lenihan, Dr. A. R. Boyle and Mr. H. G. Jones.

Regional Hospital Board) on " A Scientific Study of the Highland Bagpipe." This was an excellent and most interesting lecture given in a most attractive manner, and ended with a fine rendering on the bagpipes by Seumas McNeill of " Mairi's Wedding."

After various happy wanderings to social clubs in Thurso members completed mid-summer's night in a restful manner, and it is believed that they all successfully made the hazardous return.

A. R. BOYLE

Education Group : Summer Meeting at Dulwich College

The summer meeting of the Education Group held on Saturday, July 12, 1958, took the form of a visit to Dulwich College.

About 50 members and their guests assembled in the Lecture Theatre of the science block and

were welcomed by the Master, R. Groves, Esq., M.A., F.R.I.C.; he gave an interesting account of the history of the college, and of its present position.

Dulwich College was founded by Edward Alleyn, the famous Elizabethan actor-manager. On June 21, 1619, a licence was granted for his college of God's Gift at Dulwich—a foundation consisting in those days of a Master, a Warden, four Fellows, twelve poor scholars and twelve alms-people. By the middle of the nineteenth century the foundation had outgrown its original constitution, and in 1857 Alleyn's College was reconstituted by a special Act of Parliament. The upper part of the foundation was henceforth known as Dulwich College, and in 1870 moved to its present site.

There are now about 1,300 boys in the College, 400 in the Sixth-forms, about half taking science. This year 25 have gained open scholarships to Oxford and Cambridge, and last year 27 gained such scholarships.

The College has had a good season at rugger, and cricket and two Old Alleynians were playing for Cambridge in the Universities Match at Lord's.

After this warm welcome by the Master, the party divided up into small groups and were shown round the Art Gallery by Mr. M. R. Preston, the Arts Master. The Chapel and the Great Hall were then visited. In the Board Room many treasures were on exhibition. Amongst these were copies of the First Edition of Johnson's Dictionary, a Tyndale's Bible and the Original

Included in the photograph are Dr. E. G. Stanford, Mr. F. Y. Poynton, Mr. E. W. Tapper and Dr. L. Mullins.

Charters of the Foundation. These had been arranged by Mr. W. S. Wright.

Sir Ernest Shackleton was a boy at the College from 1887 to 1890, and the party saw photographs taken on his Antarctic Expedition, and saw the boat in which he made his famous journey. It was interesting to compare his expedition with the recent Fuchs-Hilary one.

The party had the privilege of being shown round one of the Boarding Houses, Blew House, by the Housemaster, Mr. G. A. Way.

After an excellent tea, the party showed their continued interest by spending an hour touring the Science Block. They were very much impressed by the thought and skill that had gone into the design of the laboratories and services.

The visit was enjoyed very much by all who attended, and everyone appreciated the efforts made by the boys and staff to ensure the success of the visit. The especial thanks of the Group are due to Mr. E. W. Tapper, Senior Physics Master, for his efficient organization of the visit.

T. H. TYLER.

Non-destructive Testing Group summer meeting in Paris (June 16-20, 1958)

Non-destructive testing is now being developed and extended towards a more exact study of the factors influencing service behaviour, material quality and batch consistency, and of the techniques for measuring and controlling them. The necessity for this development has been highlighted largely by the requirements of the aircraft and nuclear power industries, where, because of the operating conditions and service requirements, high quality and uniformity of properties are of prime importance.

The Non-destructive Testing Group is responsible for a certain pioneering of this approach to the fundamental aspects of the subject and, in so doing, is constantly endeavouring to bring together at its meetings and conferences industrial physicists, academic research staffs and instrument designers, all of whom must be acquainted with each other's problems, developments and requirements.

A successful attempt to extend the range of these discussions was recently held in Paris, in conjunction with the Société Française de Métallurgie, who have recently formed a " Co-ordinating Committee of French research for the applications of Non-destructive Testing methods to metals and alloys " under the Chairmanship of Monsieur P. Bastien.

It was arranged that the theme of the conference was to be the " Utilization of physical properties for studying the relationships between the constitution, structure and service behaviour of metals," for in the opinion of the Group Committee it is in the study of these relationships that the most fundamental advances are likely

to be made. Whilst many of the papers dealt rigidly with the conference theme, technical applications were also discussed in a number of contributions on recent advances in the more established techniques of defect detection.

It was, however, apparent both at the Conference, and more especially during an associated visit to the Institut de Recherches de la Siderurgie, that a considerable amount of pertinent data relating structural effects to physical properties was in fact being accumulated in France. This Conference might indeed have gone some way in bringing to light the significance of this work in relation to the fundamentals of inspection.

Chairman. Every effort was made to record the Conference proceedings, and it is proposed to publish both the papers and discussion in a special issue of the *Revue de Métallurgie*.

Apart from the visit to the I.R.S.D. Laboratories already referred to, arrangements were made for a conducted tour of the Dauphine assembly line at the Renault factory at Flins.

Throughout the Conference the Société Française de Métallurgie extended the most liberal hospitality to the British Party which was very much appreciated by all who attended. It is hoped to hold a similar conference in London in 1960, but as a spontaneous gesture to commemor-

A group at the reception.

Some of the trends in inspection that emerged from the Conference were the growing awareness of the importance of micro-structural detail (trace elements, constituent phase compositions, segregations, etc.), and a deeper understanding of the mechanisms of material failure in terms of lattice and structural irregularities. From these studies, new inspection techniques are already being evolved although many, as yet, are still in the research stage.

Some 250 members of the Société Française de Métallurgie registered for the Conference and the British party was about forty strong. The Conference included eight papers by British, and seven by French speakers, and each session was presided over by a British and a French

ate the success of the first of such joint meetings it is proposed on behalf of those present in Paris, to present to the Société Française de Métallurgie, a medal, to be awarded annually at the discretion of the Society for the most significant contribution to non-destructive testing.

Running in parallel with the Conference sessions, a most excellently organized program was arranged for the members' ladies, including visits and excursions in and around Paris.

The French organizing committee who were associated with the detailed planning of the Conference arrangements as a whole are indeed to be congratulated on all that they did to ensure the great success of this first Group venture of holding a summer meeting out of Britain.

R. S. SHARPE.

The Graduateship Examination, 1958

THE Institute's Graduateship Examination was held on June 2-6. Written papers were taken in London, Birmingham, Salford, Paisley, Swansea and Adelaide. The practical examination was held in London.

Eighty candidates took papers other than the General paper. Twenty-six satisfied the examiners in all the papers they were required to take. The successful candidates were the following (the colleges at which they studied are given in brackets) :—

A. Bland—Elizabeth South, South Australia
(*Sir John Cass College, London*)
D. B. Clayton—Wolverhampton
(*Birmingham College of Technology*)
H. Cripps—Middleton, Lancs.
(*Royal Technical College, Salford*)
P. C. Dench—Aldershot
(*Guildford Technical College*)
D. R. Easson—Bedford
(*Northampton College of Advanced Technology, London*)
F. W. K. Firk—Didcot, Berks.
(*Oxford College of Technology, Art and Commerce*)
G. R. Froud—Beckenham
(*South East London Technical College*)
O. G. Green—London
(*Northampton College of Advanced Technology, London*)
G. S. Lawson—East Kilbride
(*Paisley Technical College*)
D. J. L. Lewis—Bedford
(*University of Bristol and Sir John Cass College, London*)
D. Marsden—Sheffield
(*University of Sheffield and Rotherham Technical College*)
K. P. McDonagh—Manchester
(*Royal Technical College, Salford*)
R. H. McLaughlin—Farnborough, Hants.
(*Guildford Technical College*)
J. J. O'Shaughnessy—Great Malvern
(*Birmingham College of Technology*)
J. Plummer—London
(*Northampton College of Advanced Technology, London*)
A. C. Ponder—London
(*University of Leicester and Borough Polytechnic, London*)
J. O'D. Rowan—Glasgow
(*Paisley Technical College*)
J. M. Sawdy—Southend-on-Sea
(*Southend-on-Sea Municipal College and Sir John Cass College, London*)
H. T. Shotton—Birmingham
(*College of Technology, Birmingham*)
P. A. Smith—Windsor
(*Battersea College of Technology, London*)
B. G. Switzer—Farnborough
(*Guildford Technical College*)
H. R. Tebboth—Walton-on-Thames
(*College of Technology, Birmingham and Borough Polytechnic, London*)
N. A. West—London
(*University of Southampton*)
J. B. Willis—Reading
(*Reading University and Reading Technical College*)
R. F. Winspear—Birmingham
(*College of Technology, Birmingham*)
K. C. Winter—Wirral
(*University of Bristol*)

Of the successful candidates G. R. Froud, J. M. Sawdy, R. F. Winspear and K. C. Winter were considered by the examiners to have merited special mention and these candidates will be eligible to apply eventually for Associateship on the basis of the shorter period of experience required of graduates with high honours. It is significant to point out that in all the previous examinations only two candidates have been specially mentioned in this way.

Table I shows the qualifications held by candidates and on the basis of which most of them obtained partial exemption.

TABLE I

	Candidate	*Passed*
Holders of degrees	25	12
Holders of the Higher National Certificate in Applied Physics	47	14
Others	8	0

There were thirteen candidates for the General Paper, four of whom satisfied the examiner. Table II gives the results in each paper.

TABLE II

	No. of Candidates	*Passes*
Physics I (General Physics and Acoustics)	55	22
Physics II (Heat and Optics)	52	18
Physics III (Electricity and Magnetism)	7	3
Mathematics I...	7	2
Mathematics II	7	0
More Advanced Physics ...	26	16
Applied Optics	2	0
Electronics	19	8
Mathematical Physics ...	2	1
Nuclear Instruments and Measurements	3	1
Spectroscopy	1	1
X-rays	6	3
Practical examination ...	11	6
General paper	13	4

The papers set are reproduced below and the comments of the examiners are given on page 244. The paper in Statistics is included here although the candidates who entered for it withdrew before the examination.

Papers set in the Graduateship Examination, 1958

PURE PHYSICS I—GENERAL PHYSICS AND ACOUSTICS

Examiner : PROFESSOR J. G. WILSON, M.A., PH.D., F.INST.P.

MONDAY, 2nd June—9.30 a.m. to 12.30 p.m.

(*Answer* FIVE *questions*)

1. Explain why a suitable compound pendulum is a more accurate apparatus for the determination of the gravitational acceleration, g, than a simple pendulum. By what fraction would you expect the observed value of g at the equator to differ from that due solely to the gravitational force ?

2. Define the surface tension at the interface between two fluids, explaining clearly the units in which it is measured. Describe a method suitable for the determination of the surface tension of mercury, emphasizing precautions which you consider important.

3. Describe briefly some applications of gyroscopes, and discuss the properties required for these purposes.

Explain the conditions under which a gyroscope precesses. Why does the axis of rotation of the earth precess ?

4. Define Young's modulus, and show why this is the appropriate modulus of elasticity for the treatment of the bending of beams. A uniform beam of rectangular cross-section is simply supported at its ends and sags under its own weight. Obtain an expression for the depression of the centre of the beam.

5. State Bernoulli's theorem. To what situation does this theorem apply and how may it be derived ? Give two examples of the application of Bernoulli's theorem to the measurement of the velocity of movement of fluids.

6. Under what conditions can a group velocity differing from the phase velocity of a wave-system occur ? Derive an expression for the group velocity.

The group velocity of surface waves on water is greater than the phase velocity when the wavelength is less than 2 cm, and not so great as the phase velocity when the wavelength is greater than this value. What conclusions do you draw ?

7. Derive from elementary principles an expression for the velocity of sound waves in free air, and show how this velocity will depend upon temperature, pressure and humidity.

Discuss qualitatively the factors which will contribute to the attenuation of sound waves (*a*) in the free air, and (*b*) in narrow tubes.

8. Write a short essay on the definition and measurement of the intensitv and loudness levels of sound.

PURE PHYSICS II—HEAT AND OPTICS

Examiner : PROFESSOR H. LIPSON, M.A., D.Sc., F.INST.P., F.R.S.

MONDAY, 2nd June—2 p.m. to 5 p.m.

(*Answer* FIVE *questions, at least* TWO *from each section*)

SECTION A

1. Explain what is meant by a perfect differential. Discuss the concept with respect to heat and entropy. Thence show that an absolute thermodynamic scale of temperature is possible. Explain the theory of the heat pump and discuss its advantages. An engine of 4 horse-power operates as a heat pump between two tanks of negligible thermal capacity. If the tanks contain respectively 500 kg and 1500 kg of water at 17°C, what is the maximum temperature to which the smaller mass can be raised when the larger is reduced in temperature to 0°C by the action of the engine? How long will the process take ? (Mechanical equivalent of heat = 4·2 joule . cal.$^{-1}$. 1 horse-power = 746 watts.)

2. Discuss the phase rule and its application to the interpretation of phase diagrams of binary alloys. Show that, in general there will be a range of temperature of solidification when a binary alloy cools from the liquid state. Discuss the special conditions for which the range becomes zero.

3. Explain the principle of equipartition of energy. Discuss the effect of this principle upon the distribution of energy in the spectrum of a radiating black body and explain how the experimental results differ from those expected. Indicate how the quantum theory has eliminated the discrepancy.

4. Discuss, with examples, the use of cycles in thermodynamics. Show that, in a reversible cycle plotted on a pressure-volume diagram, the work done is equal to the area of the cycle in appropriate units. By considering such a cycle for a substance changing from liquid to vapour, find an expression for the variation of boiling point with pressure in terms of the temperature, the latent heat, the density of the vapour and the mechanical equivalent of heat.

5. Write a brief essay on humidity and the importance of its measurement and control in industry.

SECTION B

6. List the aberrations possible in an optical system and discuss Abbe's sine rule as a criterion for their elimination. Show that this rule is obeyed if a point object is placed at a distance r/n from the centre of a sphere of radius r and refractive index n. Discuss the application of this result to the oil-immersion objective.

7. Derive a general expression for the Fraunhofer diffraction pattern of an arbitrary aperture. Apply your result to a rectangular aperture.

Thence discuss the problem of the resolution of two closely-spaced sources of light by means of a telescope in front of the objective of which a rectangular aperture is placed.

8. Explain how the radius of curvature of the convex surface of a lens can be found by means of the image formed by reflection from it. How would you find the axis of a lens if you cannot assume that it has been placed accurately in its mount ? Describe clearly the procedure you would adopt to support two such lenses coaxially with a point source of light on the axis.

9. Write a brief essay on the application of the spectrometer in industry.

PURE PHYSICS III—ELECTRICITY AND MAGNETISM

Examiner : PROFESSOR J. G. WILSON, M.A., PH.D., F.INST.P.

THURSDAY, 5th June—9.30 a.m. to 12.30 p.m.

(*Answer* FIVE *questions*)

1. Show how Gauss's theorem may be established for a distribution of electrostatic charge.

A total charge e is uniformly distributed through a sphere of radius a. Derive an expression for the potential V at any point due to this distribution.

2. Describe briefly how the magnetic elements may be measured at any point on the earth, and indicate how, in a first approximation, the terrestrial field may be represented. Give an account of *either* long-term *or* short-term variations of the field.

3. How do the packing fractions (or binding energies) of atomic nuclei vary with the number of neutrons and protons in the nucleus ? What are the main conclusions to be drawn from this variation ?

4. Write a short essay on the background of observational physics in the light of which Maxwell's electromagnetic theory was developed.

5. Draw a simple circuit in which a triode valve is used for the amplification of an a.c. signal.

Discuss the considerations which determine the choice of component values, the precautions necessary if undistorted amplification is required and the features which set an upper limit of frequency for useful operation.

6. Wires of two different metals are connected in series with an applied electromotive force ; describe the two thermoelectric effects which might be observed in this circuit.

Explain how these effects are related to the potential developed in a thermocouple circuit of the same two metals.

7. What is a curie, and what do you understand by the decay constant of a radioactive material ?

An initially pure sample of a material of decay constant λ_1 decays into a second radioactive substance of decay constant λ_2.

Obtain an expression for the amount of the second substance present at any subsequent time.

8. Describe the properties which make a moving-coil galvanometer suitable for use as a ballistic galvanometer.

How would you use a ballistic galvanometer for the measurement of a magnetic field of about 1000 oersted ?

9. One plate of each of two capacitors is earthed ; one capacitor, C_1, is uncharged, the other, C_2, is charged to potential V and then isolated. If the free plates of C_1 and C_2 are now connected through a circuit of resistance R and inductance L, show how the variation of potential on C_1 depends on the values of the circuit constants. Propose an arrangement by which you would study this variation experimentally.

MORE ADVANCED PHYSICS

Examiner : PROFESSOR H. LIPSON, M.A., D.Sc., F.INST.P., F.R.S.

TUESDAY, 3rd June—9.30 a.m. to 12.30 p.m.

(*Answer* FOUR *questions*)

1. When a beam of monochromatic radiation falls upon a particle it is scattered with a change of wavelength (the Compton effect). Derive an expression for the change in wavelength as a function of the incident wavelength, the mass of the scattering particle and the angle of scattering. Describe how you would attempt to verify the relationship experimentally.

2. Given an X-ray tube and a piece of copper, how would you prove that copper had a face-centred cubic structure ? Describe the apparatus you would use and enumerate clearly the various steps in the investigation.

3. Give an outline of the theory of electrical conduction in metals and alloys. Explain clearly what is meant by (*a*) the Fermi surface and (*b*) Brillouin zones, and show the importance of the relationship between them.

4. Describe the experiment of Hahn and Strassmann that led to the conclusion that nuclear fission was possible. Explain how this experiment led to the construction of the nuclear reactor. Why does nuclear fusion hold out more hope than nuclear fission as a general method of producing energy economically ?

5. Discuss the relationship between the electron microscope and the optical microscope. Explain the measures taken to improve the limit of resolution of the electron microscope and discuss the limitations at present existing.

6. Write an essay on the nature and methods of observation of cosmic rays.

7. In the thermonuclear experiments carried out in " Zeta " the temperature of the discharge is measured by the Doppler broadening of the spectral lines. Explain this statement fully, show why it gives an absolute measurement of temperature, and state how the result is derived.

NUCLEAR INSTRUMENTATION AND MEASUREMENT

Examiner : A. E. DE BARR, B.Sc., F.INST.P.

TUESDAY, 3rd June—2 p.m. to 5 p.m.

(*Answer* FIVE *questions*)

(*The required numerical data are given at the end of the paper*)

1. Discuss the experimental verification of Einstin's relation $E = mc^2$. Assuming the energy output of the sun to arise from the synthesis of helium and that solar energy reaches the earth, $1{\cdot}5 \times 10^{11}$m away, in a flux of 0·15 watt/cm^2, determine the rate at which hydrogen is being consumed in the sun.

2. Describe the processes occurring in radioactive decay. Explain what is meant by *half life* and determine the relation between the half life and the mean life of an atom of a radioactive species.

The helium content of a uranium-bearing mineral can be used to determine the age of a mineral. In the transition from U^{238}, via Ra^{226}, to Pb^{206} the U^{238} loses eight α-particles. A given sample of a uranium-bearing mineral was found to contain $5{\cdot}1 \times 10^{-5}$ cm^3 of helium (measured at N.T.P.) per gram of mineral and $1{\cdot}05 \times 10^{-13}$ g of radium. What is the approximate age of the mineral ?

3. What is the Compton effect ? Explain the meaning of the statement that the cross-section for Compton scattering of 0·5 MeV gamma radiation is

$$0{\cdot}43 \cdot \frac{8\pi}{3} \cdot \left(\frac{e^2}{mc^2}\right)^2 = 2{\cdot}8 \times 10^{-25} \text{ cm}^2/\text{electron}$$

Over what range of energies of incident quanta is Compton scattering an important mechanism for the absorption of radiation ?

In what thickness of carbon of density 2·5 g.cm^{-3} will 5% of the energy in a beam of 0·5 MeV gamma radiation be scattered, if no other mechanism of absorption is operative ?

4. Explain the meaning and significance of

(*a*) roentgen

(*b*) roentgen-equivalent-physical (rep).

What is the relation between the roentgen dose rate and the energy absorbed in air ?

An ionization chamber has an air-equivalent-wall and its effective air volume is 100 cm^3. When placed 1 m from a radioactive cobalt-60 source of small dimensions, the ionization current developes a potential difference of 0·85 volt across a resistance of 10^{10} ohm which forms part of a dose rate meter.

(i) Estimate the thickness of lead required to reduce the dose rate at 50 cm from the source to a value of 10^{-5} roentgen/second, and

(ii) Estimate the dose rate upon the surface of a lead sphere of this radius with the source at its centre. In practice the dose rate there is found to have a rather higher value. Account for this.

5. What is meant by the *dead time* of a counter or scaler, and how does it influence the accuracy of counting of

(*a*) regular

(*b*) random pulses ?

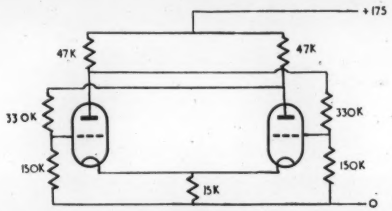
Describe a suitable electronic circuit for making the dead time of a Geiger counter have some accurately known value.

The dead time of a particular scaler is not known more precisely than that it does not exceed 100 microseconds. What is the maximum counting rate of random pulses that can be accommodated if an overall counting accuracy of 2% is required ? What would be the maximum rate for the same accuracy if the dead time was 200 microseconds and known to within 5% ?

6. Describe the action of a scale-of-two circuit using high-vacuum valves, and show by means of a block diagram how a decade scaling circuit can be constructed from a number of such circuits.

Describe briefly a gas-filled device which can also be used as a decade scaler, and compare the properties of the two scalers.

Determine approximately the currents and voltages corresponding to the stable states for the circuit shown.



(Assume the anode current/anode voltage characteristic of the triode for zero grid voltage is : anode current in milliamperes = 0·1 × anode voltage.)

7. Write an account of the conduction of electricity in gases, with particular reference to ionization chambers, proportional counters and Geiger counters.

Describe briefly a scintillation counter suitable for detecting gamma radiation and compare its properties with those of the gas-filled device that would be used for the same purpose.

8. Discuss the particular difficulties associated with the design of d.c. amplifiers, and explain some of the means that have been adopted to overcome them.

9. Show, by analysing simple circuits containing capacitance and resistance, that the mathematical processes of differentiation and integration can be performed electrically. Describe briefly the application of such circuits for pulse shaping.

A pentode amplifier stage has an unbypassed cathode resistor R_k and a load resistor R_L which is shunted by a capacitance C. If the grid voltage is decreased suddenly by one volt, calculate the output voltage as a function of time.

Numerical Data

Avogadro's number, N		$6{\cdot}025 \cdot 10^{23}$ per g molecule
Velocity of propagation of electromagnetic waves in vacuo, c		$3 \cdot 10^{10}$ cm sec^{-1}
Atomic masses	H^1	1·008142 atomic mass units
	He^4	4·003860 atomic mass units
Half lives	U^{238}	$4{\cdot}5 \cdot 10^9$ years
	Ra^{226}	$1{\cdot}620 \cdot 10^3$ years
Half value thickness of lead for Co^{60} gamma radiation		1·2 cm

ELECTRONICS

Examiner : A. E. De Barr, B.Sc., F.Inst.P.

TUESDAY, 3rd June—2 p.m. to 5 p.m.

(*Answer* FIVE *questions*)

(*The required numerical data are given at the end of the paper*)

1. Explain the meaning of the term " work function " and its significance in connection with thermionic emission.

Discuss the theoretical explanations for the changes in work function brought about by :

(*a*) strong electrostatic fields

(*b*) monatomic surface layers.

How would you measure the work function of tungsten ?

2. Explain how and why a junction transistor can be used to amplify small electrical signals.

Compare the action of a transistor with that of a valve for this purpose.

Describe and explain a suitable circuit, containing no thermionic valves, for use in converting power from a low-voltage d.c. source to d.c. power at a higher voltage. How would you measure the efficiency of such a circuit ?

3. Describe briefly the different kinds of fluctuation noise that limit the useful gain of an amplifier.

Discuss the significance of the signal-to-noise ratio of an amplifier, and explain what practical steps can be taken to improve this ratio in a valve amplifier.

What is the minimum detectable current in an electrometer amplifier the input circuit of which at 20°C consists of a 10^{12} ohm resistor with a parallel stray capacitance of 10pF ? How long would one have to wait before taking the measurement if an accuracy of at least 5% was required ?

4. Describe and explain, with diagrams and circuit diagrams to show the essential features, suitable electronic equipment for TWO of the following requirements :

(*a*) Amplification and detection of frequency-modulated signals at a carrier frequency of about 90 Mc/s.

(*b*) Frequency analysis of signals in the range 0·1—20 c/s.

(*c*) Production of a continuous record of very small changes of capacity.

5. Explain what is meant by the Miller effect and show how it affects the input capacitance of a triode valve having a resistance as the anode load. Describe briefly two practical applications of the Miller effect. The anode-grid capacitance of a triode is 4pF and the grid-cathode capacitance is 5pF. If the amplification factor of the valve is 20, determine the effective input capacitance with a resistive load. What difference would you expect if the valve were a pentode ?

6. Discuss the particular difficulties associated with the design of d.c. amplifiers.

7. Show, by analysing simple circuits containing capacitance and resistance, that the mathematical processes of differentiation and integration may be performed electrically.

A square wave whose peak-to-peak value is 1·0 volt extends ±0·5 volt with respect to earth. The duration of the positive section is 0·1 seconds and of the negative section is 0·2 seconds. If this waveform is impressed upon a resistance-capacitance differentiating circuit of time constant 0·2 seconds, what are the steady-state maximum and minimum values of the output waveform ?

8. Explain, with the aid of waveform diagrams, the action of a full-wave rectifier circuit with a condenser-input smoothing circuit. A simple valve stabilizing circuit consists of a triode with its anode connected to the positive end of an unregulated source of H.T., and with its cathode connected to one side of a 5000 ohm load, the other side of the load being connected to the negative end of the H.T. supply. The grid of the triode is held at a constant potential, positive with respect to H.T. negative, and adjusted to give linear operation of the triode. The anode slope resistance of the valve is 7500 ohms and its amplification factor is 15. If small changes of voltage occur in the unregulated source, calculate :

(*a*) The corresponding changes of load voltage.

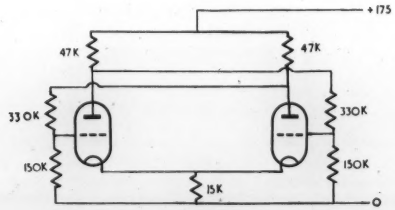
(*b*) The output impedance of the circuit as measured across the load.

(*c*) The input impedance of the circuit as seen from the H.T. source.

(Assume that the impedance of the H.T. source is negligible)

9. Describe the action of a scale-of-two circuit using high-vacuum valves, and show, by means of a block diagram and explanation, how a decade scaling circuit can be constructed from a number of such circuits. Describe briefly a gas-filled device which can also be used as a decade scaler.

Determine approximately the currents and voltages corresponding to the stable states for the circuit shown :



(Assume the anode current-anode voltage characteristic of the triode for zero grid voltage is : anode current in milliamperes = 0·1 × anode voltage.)

Numerical Data

Electronic charge, e	...	...	...	$1{\cdot}602 \cdot 10^{-19}$ coulomb
Boltzmann's constant, k	...	...		$1{\cdot}37 \cdot 10^{-23}$ joule per deg. K

X-RAYS

Examiners :

A. E. De Barr, B.Sc., F.Inst.P. ; R. F. Farr, M.A., F.Inst.P.

TUESDAY, 3rd June—2 p.m. to 5 p.m.

(*Answer question* ONE *and any* FOUR *others*)

(*The required numerical data are given at the end of the paper*)

1. What may be the biological consequences of excessive exposure of an operator to X- or gamma radiation ?

A series of protection-type films are exposed for (i) 0, (ii) 1, (iii) 2 and (iv) 4 hours at a distance of 50 cm from a tube containing 125 mgm of radium filtered by 1 mm of platinum. Similar films are worn for one week by workers A, B and C. The films are all processed together and their densities are then measured to be, respectively, (i) 0·10, (ii) 0·56, (iii) 1·02, (iv) 1·89, A 0·40, B 0·75 and C 2·30. It is believed that the workers have been exposed to radiation to which the emulsion is five times as sensitive as it is to the gamma radiation from radium. Estimate the whole-body dose received by each worker, and comment upon the results in the light of recommended Maximum Exposure Levels.

2. Explain how and why the waveforms of the intensities of the continuous and characteristic radiation from an X-ray tube in a self-rectifying circuit vary with increasing amplitude of the sinusoidal voltage applied to the primary of the high-tension transformer.

If the peak voltage applied to the tube is 10,000 volts and the r.m.s. value of the current through the tube is 5 milliamperes, estimate approximately how much X-ray energy would be incident per second on an area of one square centimetre facing the tube and one metre away from it.

3. Write an account of the principles employed in rendering X-ray equipment shockproof. Consider both the low-tension and high-tension sides of the apparatus and, in particular, show how the meters indicating the tube current and voltage, and the time-controlled exposure switch, are connected into the circuit of an X-ray generator which is centre-earthed.

What factors must be taken into account in interpreting the readings of these instruments ?

4. Discuss the importance in (i) radiography, (ii) X-ray crystallography of the condition, size and shape of the focal spot of an X-ray tube. How may these features be studied experimentally ?

A lead screen with two pinholes 8 cm apart is placed parallel to and 20 cm from a photographic film. An X-ray tube is positioned on the other side of the screen with its focal spot on a line perpendicular to the screen and passing midway between the two pinholes. The images of the focal spot on the film are 19 cm apart and are $3{\cdot}25 \times 2{\cdot}2$ and $1{\cdot}05 \times 2{\cdot}2$ mm in length and width respectively. Calculate the inclination of the target face to the plane of the screen.

5. Outline the principal physical properties of X-radiation. Show how certain of these properties may be used to obtain a measurement of (*a*) the dose rate, (*b*) the quality of a beam of X-rays.

6. Write an account of the processes by which X-rays may be absorbed and scattered. Indicate how each process contributes to the total attenuation of an X-ray beam as it passes through an absorber. What is meant by *lead equivalent* ? The lead equivalent of barium concrete is found to depend upon the thickness and upon the voltage applied to the tube producing the X-rays in the following manner :

(i) One inch of barium concrete is equivalent to

2·3	3·3	4·1	2·3	1·8 mm of lead
at 50	75	100	150	200 Kvp

(ii) At 150 Kvp the equivalent thicknesses are

0·5	1·0	2·0	3·0	inches of concrete
1·2	2·3	4·3	5·9	mm of lead

Explain, in general terms, these results.

7. It is desired to carry out routine fluoroscopic examination of articles fabricated from asbestos and contained in small cardboard boxes. Discuss the factors that determine the smallest size of a metallic foreign body that could be detected in this way. Describe the equipment you would use and the technique you would follow in carrying out this test safely and reliably. How would you choose the appropriate tube voltage and current ?

8. Describe the principles of operation of a Bragg spectrometer and describe how you would use it as a monochromator to determine the mass absorption coefficient of iron for chromium Kα radiation.

The mass absorption coefficient of a cobalt-manganese alloy containing 50% by weight of cobalt is 112·2 g^{-1} cm^2 for chromium Kα radiation. Calculate the mass absorption coefficient for manganese Kα radiation of a manganese-iron alloy containing 50% by weight of iron.

9. Explain the principles of the powder method of X-ray diffraction. Describe the construction and use of one type of powder camera and show how the Bragg angles of the reflection are obtained from the film.

The lines on a powder photograph of a substance of cubic structure correspond to the following Bragg angles : 25·4°, 29·6°, 44·3°, 55·0°, 58·83°, 81·10°.

Assign indices to these reflections and deduce the lattice type If the wavelength of the radiation used was 1·78Å calculate the size of the unit cell.

Numerical Data

X-ray wavelengths ... Nickel Kα 1·6565 Å
Manganese Kα 2·0975 Å
Chromium Kα 2·2869 Å

Mass absorption coefficients (g^{-1} cm^2)

			Radiation	
Element	*Atomic Weight*	*Atomic Number*	*Nickel Kα*	*Chromium Kα*
Chromium	52	24	316	89.9
Manganese	55	25	348	
Iron	56	26	397	
Cobalt	59	27	54	125

SPECTROSCOPY

Examiner : A. E. De Barr, B.Sc., F.Inst.P.

TUESDAY, 3rd June—2 p.m. to 5 p.m.

(*Answer* FIVE *questions*)

(*The required numerical data are given at the end of the paper*)

1. Show that the frequency of revolution of an electron in a Bohr orbit with quantum number n is

$$v_{\text{orb}} = \frac{4\pi^2 m' e^4 Z^2}{h^3 n^3}$$

where the other symbols have their usual meanings. Show then that if an electron makes a transition from a state for which $n = n_1$ to a state for which $n = n_2$ where $n_2 - n_1 = 1$, then the frequency v of the emitted radiation is intermediate between the frequencies of orbital revolution in the initial and final states. What is the relationship between the emitted and orbital frequencies when n_1 and n_2 are both very large ?

The best values of the Rydberg constants for the hydrogen and helium atoms are now considered to be $R_H = 109677{\cdot}576$ cm^{-1}, $R_{He} = 109722{\cdot}267$ cm^{-1}. Calculate accurately the value of the ratio of the mass of the hydrogen atom to that of the electron.

2. Explain what is meant by the Zeeman effect and discuss briefly its theoretical interpretation. Outline the experimental arrangement you would use to investigate the effect quantitatively.

In an applied field of 30,000 oersteds the D_2 line of sodium splits into six components, the displacements of which are $\pm 0{\cdot}47$ cm^{-1}, $\pm 1{\cdot}41$ cm^{-1} and $\pm 2{\cdot}35$ cm^{-1} respectively. Compare this pattern with that of the normal Zeeman triplet and account, in general terms, for the differences.

3. Discuss the methods that can be used to investigate the fine structure of spectral lines, and the conclusions that can be drawn about atomic structures from the data obtained.

Determine the resolving power required for investigating the distribution of intensity across a spectral line of wavelength 5000 Å and of half-width 0·1 Å, and indicate (considering dimensions) how this could be realized.

4. Discuss the type of information that can be obtained by examination of ultra-violet, visible and infra-red spectra.

Describe the main differences in the apparatus and techniques used in the study of spectra in the ultra-violet, visible and infra-red regions of the spectrum, and explain the reasons for these differences.

5. Outline the difficulties involved in obtaining quantitative spectral distribution curves by using some form of densitometer and a photograph of the spectrum. How does this method compare with the use of some form of direct photoelectric spectrophotometer in which photography is not involved ?

6. Discuss the construction and use of a double-beam infra-red spectrometer. What sort of information could be obtained with such an instrument about (*a*) a polymer that is known to contain –OH groups, (*b*) a heteronuclear diatomic molecule such as HCl ?

7. Why are arc, spark and flame spectra of the same element not, in general, identical ? In what circumstances would each of these methods of excitation be used ?

Describe the construction and operation of a multi-source unit for the excitation of arc and spark spectra.

8. Write brief notes on (*a*) Microwave spectra
(*b*) Raman spectra
(*c*) Internal standards.

Numerical data

Electronic charge, e	$1{\cdot}602 \cdot 10^{-19}$ coulomb
Electronic mass	$9{\cdot}107 \cdot 10^{-28}$ g.
Velocity of propagation of electromagnetic waves in free space	$3 \cdot 10^{10}$ cm sec^{-1}

APPLIED OPTICS

Examiners :

A. E. De Barr, B.Sc., F.Inst.P. ; C. A. Taylor, B.Sc., Ph.D., F.Inst.P.

TUESDAY, 3rd June—2 p.m. to 5 p.m.

(*Answer* FIVE *questions*)

1. Discuss the following lens aberrations, explaining carefully under what circumstances they arise and how they may be measured : spherical aberration, chromatic aberration and astigmatism. Describe the methods available for correcting or compensating for these aberrations.

2. Describe the optical system of a small refracting telescope giving an erect image. Suggest suitable focal lengths and diameters for the component lenses to give a magnifying power of about 20. A telescope is constructed of two thin converging lenses of focal length 20 cm and 2 cm respectively. The telescope is in normal adjustment for parallel light, and a stop 0·5 cm in diameter is placed in the back focal plane of the objective. The objective is 2 cms in diameter and the eyepiece is 0·6 cm in diameter. The observer's eye has a pupil of 0·4 cm diameter and is placed at the exit pupil of the telescope. Determine (*a*) the location and size of the entrance pupil of the system, (*b*) the location and size of the exit pupil of the system, (*c*) which component acts as field stop.

The 0·5 cm stop is then replaced by one 2 cm in diameter. What effect does this have on your answers to (*a*), (*b*) and (*c*) above ?

3. Discuss the principal factors to be considered in the optical design of a high-grade industrial measuring instrument (such as a comparator, an alignment telescope or a jig-borer's microscope).

An autocollimator is used with a plane mirror on a tripod stand to measure the surface flatness of a machine bed. The tripod is placed at 12 successive positions 3 inches apart and the autocollimator readings for these positions are 7′ 0″, 7′ 5″, 6′ 5″, 6′ 30″, 6′ 5″, 5′ 30″, 5′ 0″, 4′ 0″, 3′ 20″, 3′ 5″, 3′ 25″, and 4′ 5″ respectively. The feet of the tripod are 3 inches apart longitudinally. Find the centre line average departure from flatness, and the maximum departure from the centre line, both above and below.

4. Write an essay on " The Eye and Vision," paying special attention to the following topics : sensitivity, variation of sensitivity with wavelength under various conditions, factors affecting visual acuity, and any theory of colour vision which you have studied.

5. Explain the following phenomena :

(*a*) If a sheet of mica is placed between crossed nicols or crossed polarizing films and is rotated, the light transmitted through the system will, in general, rise to a maximum and fall to zero once every quarter of a revolution.

(*b*) When an object is viewed through a crystal of Iceland spar, in certain directions the image appears doubled but in other directions it remains single.

(*c*) Polarizing films may be used to eliminate unwanted reflections from the glass of a picture frame during photography of the picture.

6. Explain carefully, with an outline of the theory, how a glass surface may be made highly reflecting or almost non-reflecting by the deposition of a suitable layer of transparent dielectric material. A film of refractive index 1·4 is deposited on a glass of refractive index 1·6 and the thickness of the film is adjusted to give minimum reflection at a wavelength of 5500Å and normal incidence. Calculate the effective reflection coefficient for a wavelength of 6500 Å.

7. Describe and account for the differences in appearance between a set of Newton's rings and the fringes formed by a Fabry-Perôt étalon, both in monochromatic light of the same wavelength. A Fabry-Perôt étalon with an air gap between the plates is set up in a chamber which can be evacuated. The plates are accurately parallel, 0·5 cm apart, and the fringes are observed with light of wavelength 5890Å. Calculate the effect on the pattern as the air is slowly removed from the chamber. Assume the refractive index of air at N.T.P. to be 1·0003.

8. Write an account of the optical methods used for small-scale surface topography.

9. Outline the general principles of colour photography. Describe and explain one process in detail from the point of view of the physical principles and colour theory involved ; details of any chemical processes involved are not required. Assume that you are photographing a test card consisting of red, blue, green, yellow, black and white patches, and describe the changes occurring in the plates or films at each stage of the process.

MATHEMATICAL PHYSICS

Examiner : A. W. GILLIES, B.Sc., PH.D., F.INST.P.

TUESDAY, 3rd June—2 p.m. to 5 p.m.

(*Answer* FOUR *questions*)

1. The kinetic energy T, and potential energy V, of a mechanical system with co-ordinates x and y are

$$T = 5\dot{x}^2 + 8\dot{x}\dot{y} + 5\dot{y}^2$$
$$V = 9x^2 + 12xy + 6y^2$$

Determine the normal co-ordinates of the system and the periods of its normal modes. If at $t = 0$ the system is released from rest in the position $x = 1, y = 0$, determine the subsequent motion.

2. A wire, bent into the form of a circle of radius a, rotates about a vertical diameter with fixed angular speed w. A small ring of mass m slides freely on the wire. Show that its equation of motion is

$$a\ddot{\theta} + g \sin\theta - aw^2 \sin\theta \cos\theta = 0$$

where θ is the angle the radius through the ring makes with the downward vertical. Show that if $aw^2 > g$ there will be a position of stable equilibrium of the ring relative to the wire, with $\theta = \alpha$, where $\cos\alpha = g/(aw^2)$, and that the period of small oscillations about this position is $2\pi/(w \sin\alpha)$.

3. Determine a solution of the equation

$$\frac{\partial^2 v}{\partial x^2} + \frac{\partial^2 v}{\partial y^2} = 0$$

valid within a rectangle $0 \leqslant x \leqslant a$, $0 \leqslant y \leqslant b$, which vanishes on three sides of the rectangle, and on the fourth side, $y = b$, assumes the constant value v_0.

4. A thin wire is stretched between two terminals distant l apart. At $t = 0$ when the wire and its surroundings are at temperature $\theta = 0$, a constant direct electric current commences to flow through the wire. Taking account only of conduction of heat along the wire, (i.e. considering loss of heat from the surface, thermoelectric effects, etc., to be negligible) and assuming that the terminals remain at $\theta = 0$, show that the temperature at a distance x from one end will satisfy an equation of the form

$$k\frac{\partial^2\theta}{\partial x^2} + H = \frac{\partial\theta}{\partial t}$$

where k is the thermal diffusivity, and H is the ratio of the total heat produced in the wire per unit time to its thermal capacity. Show that the solution of this equation is

$$\theta = \frac{Hx(l-x)}{2k} - \sum_{n=1}^{\infty} \frac{4Hl^2}{(2n-1)^3\pi^3 k} e^{-\frac{(2n-1)^2\pi^2 kt}{l^2}} \sin\frac{(2n-1)\pi x}{l}$$

5. Obtain an expression for the potential, at a general point, due to a short magnet of moment M, situated at the origin, with its axis along the z-axis.

A second short magnet of moment M' is at a point distant r from the first magnet. Show that their mutual potential energy is

$$\frac{MM'}{4\pi\mu r^3}\left[\cos\alpha - 3\cos\theta\cos\theta'\right]$$

where α is the angle between their axes, and θ, θ' are the angles their axes make with the line joining them.

6. Two long thin parallel wires perpendicular to the xy-plane intersect this plane at $A(a, 0)$, $B(-a, 0)$ respectively. The wires carry charges q and $-q$ respectively per unit length. Show that the potential at a point P of the xy-plane, external to the wires is

$$V = C + \frac{q}{2\pi\varepsilon}\log\frac{BP}{AP}$$

Show that the equi-potential surfaces are cylinders whose traces in the xy-plane are a set of co-axial circles having A and B as limit points.

Deduce an expression for the capacity per unit length of a thin wire of radius ρ parallel to and distant h from an infinite conducting plane.

7. (i) Show that div $(\mathbf{E}\wedge\mathbf{H}) = \mathbf{H}\,\mathbf{rot}\,\mathbf{E} - \mathbf{E}\,\mathbf{rot}\,\mathbf{H}$

(ii) From Maxwell's equations derive

$$\iint\mathbf{E}\wedge\mathbf{H}\,.\,\hat{\mathbf{n}}dS = -\iiint\sigma\mathbf{E}^2dv - \frac{\partial}{\partial t}\iiint(\tfrac{1}{2}\mu\mathbf{H}^2 + \tfrac{1}{2}\varepsilon\mathbf{E}^2)dv$$

and discuss the physical meaning of this equation.

8. A body A moves with speed u along the x axis of an inertial frame S, while S moves with speed v in the same direction relative to a frame S'. Determine the speed u' of A as measured by an observer in S' and show that if u and v are both less than the velocity of light c, then u' is also less than c.

9. The potential energy of an electron in a certain one-dimensional field is $v(x)$ where

$$V(x) = \begin{cases} V_0 (x<0) \\ V_1 (x>0) \end{cases}$$

V_0 and V_1 being constants. A stream of electrons of energy $W > V_1$ enters the field from $x = -\infty$. Discuss its motion through the field, indicating the fundamental difference between the results. suggested by classical and wave mechanics.

STATISTICS

Examiner : E. D. VAN REST, M.A., B.Sc., F.INST.P.

TUESDAY, 3rd June—2 p.m. to 5 p.m.

(*Candidates should not answer more than* FOUR *questions and should include in these one of the first three*)

1. Five laboratories are asked to carry out six replicate hardness tests each on the same sheet of cured resin. They return the following results :—

Laboratory						
A	1·118	1·045	1·084	1·165	1·156	1·150
B	1·133	1·162	1·002	1·202	1·306	1·254
C	1·092	1·084	1·210	1·059	1·115	1·041
D	1·032	1·021	0·949	1·114	1·500	1·105
E	1·156	1·227	1·162	1·210	1·194	1·234

Give estimates of the standard deviations (*a*) of tests made in any one laboratory, (*b*) of all the tests reported and (*c*) of means of two tests from each of the laboratories.

What is the greatest difference one would reasonably expect (95% confidence) between the mean of two tests made at one laboratory and the mean of two made at another on portions from the same well-mixed liquid ?

2. A firm employing 105 work-people of approximately the same age, experiences a disturbing number of single-day absences. The records over 25 weeks (125 working days) showed that out of 1,885 lost man-days the single-day absences for the period were distributed over the days of the week as follows :—Mondays 264, Tuesdays 250, Wednesdays 242, Thursdays 264, Fridays 240. Are there grounds for suspecting these absences are more likely on some days of the week than on others ? What is the point of segregating single-day absences from the longer ones ?

3. The mean orbital period in minutes of Sputnik 2 was reported on four separate dates to be : November 9, 1957, 103·490 ; December 3, 1957, 102·289 ; January 22, 1958, 99·206 ; March 2, 1958, 96·330. (*Nature*, March, 1958). Supposing a constant rate of decrease of orbital time over this period, estimate this rate by fitting a regression to these data. If it were deduced from the several individual observations, of which these are the means, that the standard deviations of the means are all the same and approximately 0·01 minute, would you consider the supposition of a constant rate of decrease a tenable one ? Support your answer with reasons and calculation.

4. Show that the sum of the squared deviations of a set of values of a variable from any value A is least when A is the mean of the set. Being given this sum of squared deviations from the mean for a known number of observations but not knowing the form of their distribution, what is it possible to say about the proportion of observations deviating more than, say B from the mean ?

Given that the sum of 1,000 winning lottery ticket numbers (not all numbers printed were sold) is $5 \cdot 10^5$ and that the sum of the squares of the numbers is $30 \cdot 10^7$ what is the smallest range of numbers you would feel confident would include at least 99% of the numbers ?

5. From ten independent observations of the specific gravity of a sample of liquid the standard deviation of the test method is estimated to be 0·1 units and the mean 1·15. Is this mean value significantly different from an expected value of 1·10 ? Explain the reasoning involved in any test you make to support your answer. Taking $(n-1)s^2/\sigma^2$ to be distributed as χ^2, where s is the estimated and σ the true standard deviation, use the table of χ^2 to give confidence limits for s. Explain why these limits are not needed in a test of significance appropriate for the first part of the question.

6. An acceptance sampling scheme reads : " from each lot examine 120 chosen at random ; if more than 3 are faulty reject the lot, otherwise accept the lot." Calculate the frequency with which lots containing 3% faulty articles will be accepted in the long run by such a scheme. State what is an operating characteristic of an acceptance scheme ; calculate several other points on the operating characteristic of this one and estimate from them the greatest value the out-going quality can take.

7. A warehouse truck would be expected to run empty no more than half of its running time. In 252 of a series of 441 snap observations taken at random over a period the truck was observed to be running but empty. Does this support the suspicion that the true proportion of empty running time is greater than 0·5? Give calculations and supporting reasons for your answer.

Make a table or draw a graph, showing the probabilities that an observed value will lie outside the range 0·45 to 0·55 for various values of the departure of the real value of p from 0·5 with this number of observations and similarly with 900 observations.

8. Write a short account of ONE of the following :—

Quality control of a process by measurement of small samples of the product.

The normal distribution.

Student's t distribution.

MATHEMATICS I

Examiner : A. W. GILLIES, B.Sc., PH.D., F.INST.P.

WEDNESDAY, 4th June—9.30 a.m. to 12.30 p.m.

(*Answer* SIX *questions*)

1. (i) Solve the equation

$$\begin{vmatrix} 3-x & 3 & 4 \\ 1 & 4-x & 5 \\ 5 & 3 & 2-x \end{vmatrix} = 0$$

(ii) Determine correctly to two places of decimals the positive root of the equation

$$x^4 + x - 16 = 0$$

2. Solve the differential equations

(i) $y\frac{dy}{dx} + xy^2 = x$ with $y = 0$ when $x = 0$

(ii) $(3x - 2y)\frac{dy}{dx} = 2x - 3y$ with $y = 0$ when $x = 1$.

3. a and $\bar{a}$ are conjugate complex constants, and α is a real constant. The variable complex numbers w and z satisfy

$$w = e^{i\alpha} \cdot \frac{z-a}{z-\bar{a}}$$

Show that if a is in the upper half of the z plane, then a point z in the upper half-plane, is transformed into a point w within the unit circle with centre at the origin of the w-plane. Determine a and α if $z = \infty$, 0, 1 are transformed to $w = i$, -1, $-i$, respectively.

4. (i) Show that $\int_0^1 \frac{3x\,dx}{1+x^3} = \frac{\pi}{\sqrt{3}} - \log 2$

(ii) Evaluate $\int_C (x\,dy - y\,dx)$ where C is the circle with centre at O and radius a.

5. A crank OA' of length a rotates about an axis through O with constant angular speed w. A piston P, moving on a line OX, is joined to the crank by a connecting rod AP of length b. Express the distance $OP = x$ as a function of t and show that its Fourier expansion is of the form

$$x = a\cos wt + \sum_{n=0}^{\infty} A_{2n} \cos 2nwt$$

If b is large compared to a, show further that approximately

$$A_0 = b - a^2/(4b) \text{ and } A_2 = a^2/(4b)$$

6. (i) Forces of equal magnitudes act at points P and Q respectively. Prove that the moment of the first force about the line of action of the second is equal in magnitude to the moment of the second about the line of action of the first.

(ii) $\hat{\mathbf{a}}$, $\hat{\mathbf{b}}$ and $\hat{\mathbf{c}}$ are a right-handed set of mutually perpendicular unit vectors. If $\mathbf{r} \cdot \hat{\mathbf{a}} = 2$ and $\mathbf{r} \wedge \hat{\mathbf{a}} = 3\hat{\mathbf{b}} - 4\hat{\mathbf{c}}$ express $\mathbf{r}$ in terms of the three unit vectors.

7. Determine the volume of the solid of revolution generated when a circle in the xy-plane with centre at $(0, b)$ and radius a ($< b$) is rotated about the x-axis.

A uniform body of mass M has the form of this solid of revolution. Show that its moment of inertia about the x-axis is $M(b^2 + \frac{3}{4}a^2)$.

8. (i) If $x_1, x_2 \ldots x_n$ form a set of n numbers whose arithmetic mean is $\bar{x}$ show that the sum

$$\sum_{r=1}^{n} (x_r - X)^2$$

has its minimum value for variation of X when $X = \bar{x}$.

(ii) A quantity is measured by two methods for which the standard errors of a single measurement are 0·2 and 0·1 respectively. The first method gave 8·74 as a mean of 5 measurements, the second gave 8·66 as a mean of 3 measurements. Determine the most probable value of the quantity, and its standard error.

9. A uniform heavy elastic string of mass M and unstretched length l_0 hangs vertically, and is pulled by a force F at its lower end. If the tension at any point of the string is λ times the extension at that point, prove that the length of the string is given by

$$l = l_0\{1 + (1/\lambda)(F + \tfrac{1}{2}\mathrm{Mg})\}$$

MATHEMATICS II

Examiner : A. W. GILLIES, B.Sc., PH.D., F.INST.P.

WEDNESDAY, 4th June—2 p.m. to 5 p.m.

(*Answer* SIX *questions*)

1. By expressing as a sum of partial fractions, or otherwise, expand the function

$$\frac{1+x}{1-3x+2x^2}$$

in ascending powers of x, obtaining the coefficient a_n of x^n. Determine the interval of convergence of the series, and show that if $n > 1$

$$a_n - 3a_{n-1} + 2a_{n-2} = 0$$

2. Sketch the curve represented by the equation

$$y^2 = x^2(4 - x^2)$$

Determine the area of a loop, and show that the mean centre of one loop is at

$$x = 3\pi/8,\ y = 0$$

3. The displacement x at time t of an oscillatory system satisfies the equation

$$\frac{d^2x}{dt^2} + 2a\frac{dx}{dt} + w^2x = F\cos wt$$

in which a, w, A are constants. Determine the solution for which $x = 0$ and $dx/dt = 0$ at $t = 0$ Show that if a^2 is negligible in comparison with w^2 the solution reduces to

$$x = \frac{F}{2aw}(1 - e^{-at})\sin wt$$

and deduce from this the form of the solution when $a = 0$

4. (i) The surface density of charge on an electrified sphere of radius a is $\sigma(1 - 3\cos^2\theta)$ at points with co-latitude θ, σ being a constant. Determine the total charge on the sphere.

(ii) Evaluate $\iiint z\,dx\,dy\,dz$ over the space

$$0 < z < 1 - \tfrac{1}{4}x^2 - \tfrac{1}{2}y^2$$

5. If $x = u^2 - v^2$, $y = 2uv$ and φ is a function of u and v, and therefore also of x and y, prove

(i) $$u\frac{\partial\varphi}{\partial u} + v\frac{\partial\varphi}{\partial v} = 2\left[x\frac{\partial\varphi}{\partial x} + y\frac{\partial\varphi}{\partial y}\right]$$

(ii) $$\frac{\partial^2\varphi}{\partial u\partial v} = 2\frac{\partial\varphi}{\partial y} + 2y\left(\frac{\partial^2\varphi}{\partial y^2} - \frac{\partial^2\varphi}{\partial x^2}\right) + 4x\frac{\partial^2\varphi}{\partial x\partial y}$$

6. Solve the simultaneous differential equations

$$\frac{dy}{dt} + ay = w(x - a)$$

$$\frac{dx}{dt} + \alpha x = wy$$

with the initial conditions $x = y = 0$ at $t = 0$, α, w, a being constant. Show that immediately after $t = 0$, x will be greater than y.

7. $\mathbf{V}$ is a vector function of a variable t. Define the differential coefficient $d\mathbf{V}/dt$ and show that if $\mathbf{V}$ is of constant length $d\mathbf{V}/dt$ is perpendicular to $\mathbf{V}$.

A particle moves along a plane curve. Show that its acceleration has components of magnitudes $Vdv/d\sigma$ tangential to the curve and V^2/ρ normal to the curve, where σ is the arc length, ρ the radius of curvature, and V is the speed.

8. Show that the equation of the tangent plane at the point $P(4/3, 2/3, 1/3)$ on the spheroid

$$\frac{x^2}{4} + y^2 + z^2 = 1$$

is $x + 2y + z = 3$. Obtain the equations of the normal at P and show that it cuts the surface again at $Q(4/7, -6/7, -3/7)$.

9. OP, PQ are rods of equal length and negligible weight, freely pivoted at P. A particle of mass M is carried at P, and one of mass M' is carried at Q which can slide freely along a vertical through O. The whole system rotates about the vertical through O, while the upper rod is capable of turning about a horizontal axis through O. Show that steady motion is possible with P describing a horizontal circle in a plane at a distance below O equal to

$$\frac{M + 2M'}{M} \cdot \frac{g}{w^2}$$

PRACTICAL PHYSICS

Examiners :

A. E. De Barr, B.Sc., F.Inst.P. ; J. Yarwood, M.Sc., F.Inst.P.

FRIDAY, 6th June

(*Six hours allowed*)

(*Two questions, selected by the Examiners, will be allotted to each candidate*)

1. For the thermojunction provided, find the change of e.m.f. per degree centigrade change of temperature. Assume that the e.m.f. against temperature curve for the thermojunction is linear.

2. In accordance with the instructions given, fill the Geiger-Müller tube body with a mixture of argon and alcohol vapour and determine the Geiger threshold voltage and the slope of the plateau of the characteristic.

3. Find the wavelength of the light from a given monochromatic source by means of interference fringes produced by Lloyd's single mirror.

4. Determine Young's modulus for the material of the bar by means of a strain gauge.

5. By making use of the cut-off effect in a miniature diode valve used as a magnetron, find the magnetic flux density within the given solenoid for various values of the current through the winding.

6. Investigate as fully as possible the characteristics of the transistor provided.

7. Determine the temperature corrections necessary at various temperatures above 1000°C to allow for the insertion of the given block of glass between an optical pyrometer and the standard temperature source.

8. Determine the ultimate low pressure obtained by a mercury diffusion pump with rotary fore-pump by means of a hot-cathode ionization gauge. The calibration of the gauge for dry air is given and is assumed to apply.

9. Find the positions of the cardinal points for the lens system where the object is in air and the image is in water.

10. Find the capacitance and the power factor of the given capacitor by means of a Schering bridge.

GENERAL PAPER

Examiner : N. CLARKE, B.Sc., F.INST.P.

TUESDAY, 3rd June—9.30 a.m. to 12.30 p.m.

(*Answer questions* ONE *and* TWO *and any* THREE *others*)

1. Give the substance of the following passage in your own words :

" Of all the intellectual hurdles which the human mind has confronted and has overcome in the last fifteen hundred years, the one which seems to me to have been the most amazing in character and the most stupendous in the scope of its consequences is the one relating to the problem of motion—the one which perhaps was hardly disposed of by Galileo, though it received a definitive form of settlement shortly after his time in the full revised statement of what every schoolboy learns to call the law of inertia. On this question of motion the Aristotelian teaching, precisely because it carried such an intricate dovetailing of observations and explanations—that is to say, precisely because it was part of a system which was such a colossal intellectual feat in itself—was hard for the human mind to escape from, and gained a strong hold on medieval scholastic thought. Furthermore, it remains as the essential background of the story—it continues to present the presiding issue—until the time of Galileo himself ; in other words, until the first half of the seventeenth century. On the Aristotelian theory all heavy terrestrial bodies had a natural motion towards the centre of the universe, which for medieval thinkers was at or near the centre of the earth ; but motion in any other direction was violent motion, because it contradicted the ordinary tendency of a body to move to what to was regarded as its natural place,

Such motion depended on the operation of a mover, and the Aristotelian doctrine of inertia was a doctrine of rest—it was motion, not rest, that always required to be explained. Wherever this motion existed, and however long it existed, something had to be brought in to account for it.

" The essential feature of this view was the assertion or the assumption that a body would keep in movement only so long as a mover was actually in contact with it, imparting motion to it all the time. Once the mover ceased to operate, the movement stopped—the body fell straight to earth or dropped suddenly to rest. Further—a point that will seem very heretical to the present day—it was argued that, provided the resistance of the medium through which the body passed remained a constant, the speed of the body would be proportionate to what we should describe as the force consistently being exerted upon it by the mover. A constant force exerted by the mover over a given length of time produced not any acceleration at all, but a uniform motion for the whole period. On the other hand, if there was any variation in the resistance of the medium—the difference between moving in air and moving in water, for example—the speed would vary in inverse proportion to this, provided the other factors remained constant. And if the resistance were reduced to nought, the speed would be infinite ; that is to say, if the movement took place in a vacuum, bodies would move from one place to another instantaneously. The absurdity of this was one of the reasons why the Aristotelians regarded a complete void as impossible, and said that God Himself could not make one.

" It is astonishing to what a degree not only this theory but its rivals—even the ones which superseded it in the course of the scientific revolution—were based on the ordinary observation of the data available to common sense. And, as writers have clearly pointed out, it is not relevant for us to argue that if the Aristotelians had merely watched the more carefully they would have changed their theory of inertia for the modern one—changed over to the view that bodies tend to continue either at rest or in motion along a straight line until something intervenes to stop them or deflect their course. It was supremely difficult to escape from the Aristotelian doctrine by merely observing things more closely, especially if you had already started off on the wrong foot and were hampered beforehand with the whole system of interlocking Aristotelian ideas. In fact, the modern law of inertia is not the thing you would discover by mere photographic methods of observation—it required a different kind of thinking-cap, a transposition in the mind of the scientist himself ; for we do not actually see ordinary objects continuing their rectilinear motion in that kind of empty space which Aristotle said could not occur, and sailing away to that infinity which also he said could not possibly exist ; and we do not in real life have perfectly spherical balls moving on perfectly smooth horizontal planes—the trick lay in the fact that it occurred to Galileo to imagine these."

Herbert Butterfield
(*The Origins of Modern Science*)

2. Write an essay on one of the following subjects :—

Ships
Science and Religion
The " Eleven-Plus " Examination
Disarmament
New Towns

3. What do you consider to be the essential qualities of a good teacher of science ? What weaknesses have you found among teachers ?

Discuss the advantages and disadvantages of being a school teacher of science rather than an industrial scientist.

4. It is expected that the Government will issue this year a first list of men and women upon whom life peerages will be conferred so as to enable them to sit in the House of Lords, without conferring the same right upon their descendants. Give relevant details to justify your selection of six people (men or women) distinguished in literature, science, politics, industry or public affairs who would, in your opinion, be suitable life peers.

5. EITHER (*a*) What do you understand to be the most important principles, objectives or policies of the Conservative, Labour, Liberal and Communist parties of Britain ? Give any relevant historical facts.

OR (*b*) Describe the distinctive beliefs or forms of organization which characterize the following branches of the Christian Church : (i) Roman Catholic Church, (ii) Church of England, (iii) Methodist Church and (iv) Society of Friends. What do you know of the origins of (ii), (iii) and (iv) ?

6. Discuss the qualities that should be shown by a good newspaper. According to these standards, which is the best newspaper published to-day in Britain ? Do you read it ? If you do not—why not ?

7. Discuss the effects of television on social life in Britain.

COMMENTS BY THE EXAMINERS

Pure Physics I — Professor J. G. Wilson

Fifty-five candidates answered this paper, and while there were probably fewer very weak efforts than in recent years the general standard is still disturbingly low. Perhaps the most widespread fault is lack of ability to separate the relevant answer to a particular question from the sequence of topics within which it has been learned. In course of writing a great deal that is not wanted some candidates lose sight altogether of the specific question asked. The following notes refer to individual questions :

Q.1. (46 answers) This question was not on the whole well done. Many candidates, having listed fairly adequately the drawbacks of a simple pendulum, did not make it clear which of these could be corrected for, which are avoided by the use of a suitable compound pendulum and which remain even with the compound pendulum. A few candidates gave good descriptions of a refined reversible pendulum, but many more discussed only the laboratory equipment consisting of perforated rod and movable knife-edges, used in a manner in which its performance rarely equals, let alone surpasses, the simple pendulum.

Q.2. (36 answers) One quarter of all candidates gave wrongly the units in which surface tension is measured, while seven others gave no clear statement of units. The usual incorrect form was " dyne/cm^2 " (six scripts), to which, in one example, the explanation " a dyne being a force of one gram weight " was added, but one candidate each gave as units " dyne-cm," " gm/cm " and " poise." Far too many candidates showed no awareness of the obvious difficulties in applying some standard methods to mercury.

Q.3. (6 answers) One answer was good, the remainder were descriptive with little or no physical content.

Q.4. (49 answers) Almost all candidates had the correct general idea as to what Young's modulus is, but only a few defined it precisely in well-chosen words. Only a few also gave a really clear explanation of its application to the bending of beams. There were only two or three near-correct answers to the rider, for many candidates did not treat the problem of a distributed load, while there seemed to be general difficulty in writing down a correct statement of the equilibrium of a section of beam.

Q. 5. (28 answers) The answers to this question were disappointing, for they gave a strong impression of something that had been learned but never really understood. This applies particularly to the way in which pressure comes to appear in the theorem.
Q. 6. (17 answers) Although group velocity was generally understood in a descriptive way, the derivation of an expression for it proved very difficult to some candidates. The rider asked for simple deductions from given facts, but it attracted discursive discussions of gravity waves and of ripples which rarely led to a straight answer.
Q. 7. (34 answers) No answers of distinction came from this question but there were also a few very bad ones, although far too many candidates introduced the adiabatic modulus of elasticity without comment. The variation of velocity with pressure, temperature and humidity gave the expected spread from good to bad answers, but only two or three referred to changes both of density and of γ with varying humidity.
Q. 8. (19 answers) Most of those attempting this question had a general understanding of the subject but units were not very well defined.

Physics II — Professor H. Lipson

Although only about a third of the 52 candidates succeeded in obtaining a pass mark, there were a few who obtained a reasonably good standard. Nevertheless, the unpalatable fact must again be recorded that marks were gained mainly on bookwork and that signs of original thinking and capacity to solve problems were very slight. The following are detailed comments on the answers :
Q. 1. (34 answers) Although the necessary thermodynamic theory was generally adequately stated, not a single candidate was able to solve the problem on the heat pump. (Most candidates treated it as a " heat lost = heat gained " problem —fifth-form stuff !)
Q. 2. (17 answers) The phase rule was well known and there were some really good accounts of its application to binary alloy systems, but most answers were too diffuse.
Q. 3. (18 answers) Few candidates realized that the law of equipartition of energy applies to general systems, not merely to systems of atoms or molecules. Most candidates knew the basic facts concerning black-body radiation and their influence on the introduction of quantum theory, but few could explain the physical principles.
Q. 4. (45 answers) There were several good accounts of the use of cycles in thermodynamics and the proof of the Clausius-Clapeyron equation was well carried out. (Bookwork !)
Q. 5. (10 answers) The essays on humidity were generally poor ; there was little evidence of design and the matter introduced was often of far too elementary a level.
Q. 6. (28 answers) Candidates were well acquainted with lens aberrations, but knew little of Abbe's sign condition. The derivation of the aplanatic points of a sphere—a very simple problem—was poorly carried out.
Q. 7. (36 answers) Candidates did not appear to understand this question ; many could derive the expression for the diffraction pattern of a slit, but could not give the expression for a general aperture. Then they could not apply the result derived, but preferred to quote the expression for the limit of resolution for an ordinary lens, which was not asked for. Here was a chance for some simple original thinking, and few took, it !
Q. 8. (9 answers) The few candidates who attempted this question failed to understand it. The use of Boys' points for finding the axis of a lens is apparently not well known.
Q. 9. (25 answers) The essays on the use of the spectrometer in industry were generally poor. There was plenty of material to choose from but candidates often went outside the field ; for example, Zeta is not yet an industrial instrument !

Pure Physics III — Professor J. G. Wilson

Only seven candidates attempted this paper and it is accordingly difficult to make general comment of the work. The standard, however, was lower than the passing percentage would suggest, for all of the passes were marginal while the failures were not. The following notes refer to individual questions to which more than three candidates gave answers :
Q. 1. (5 answers) There were no good answers, and in particular no candidate made any useful progress in determining the potential inside the charge distribution given in the rider.
Q. 5. (5 answers) Only one drawing included a reasonable input connection ; the remaining drawings all showed other faults, one having no output connection at all. The section on undistorted amplification was the only part to receive worth-while answers.
Q. 7. (5 answers) The first part was fairly well done but in most attempts at the second part errors almost appeared at the outset. There was one correct answer to this part.
Q. 8. (7 answers) All candidates attempted this question and three of the answers were moderately good. It is the weakness of half of the answers to a question such as this which emphasizes how

far short of any reasonable standard some candidates in this examination fall. Comment made in 1957 relating to a question on the moving coil galvanometer applies with equal force this year.

More Advanced Physics — Professor H. Lipson

It is pleasant to record that more than half of the 26 candidates were successful in passing this examination ; there was a noteworthy competence in much of the theoretical work, although there was also a surprising lack of familiarity with some experimental aspects. These points are brought out in more detail in the following comments :

Q. 1. (25 answers) Candidates generally dealt with the Compton effect in a workmanlike manner, and several of those who failed to complete the mathematics successfully obviously knew how it should be done and quoted the result correctly. But few knew how Compton verified the result experimentally.

Q. 2. (17 answers) Few candidates knew how to derive the structure of copper. They made passable attempts at describing some form of X-ray diffraction goniometer, but were generally not aware that X-ray tubes emit characteristic radiation. They also apparently thought that copper normally occurs in large cubical single crystals !

Q. 3. (14 answers) There were some very good accounts of the theory of electrical conduction. Perhaps the weakest point generally was the lack of appreciation of the role of Pauli's exclusion principle in causing the conduction electrons to have high energies.

Q. 4. (10 answers) The problems of nuclear fission were on the whole well treated, although there seems already to be a tendency to treat the discovery made by Hahn and Strassmann as a purely routine matter. (It is a pity that remarkable discoveries of this sort should be treated in such a pedestrian way). Few candidates mentioned that one of the advantages of nuclear fusion would be that there is no radioactivity problem.

Q. 5. (10 answers) The relationship between the electron microscope and the optical microscope seemed well understood. One candidate gave an extremely clear tabular comparison (including the financial aspect !), and one gave an elaborate seven-page theoretical account, which was not what was asked for.

Q. 6. (14 answers) There were several really knowledgable accounts of cosmic rays ; the main weakness again was in the description of experimental apparatus. For example, few candidates mentioned the use of magnetic fields in conjunction with cloud chambers.

Q. 7. (4 answers) Candidates had a fair idea of the basic principles of the measurement of the temperature in Zeta from the broadening of spectral lines, but they did not work out the relationship in detail.

Applied Optics — Mr. A. E. de Barr and Dr. C. A. Taylor

It was particularly noticeable that both candidates showed a tendency to write down all they knew about the subject without relating their remarks to the actual question asked, thus suggesting that they did not really understand the subject and were relying on memory. Very few of the answers reached the standard required for this examination.

Electronics — Mr. A. E. De Barr

Candidates (and others) who thought that the questions in this paper were too difficult may be interested to learn that questions 1, 2, 3, 5, 6 and 8 were taken—with little or no alteration— from last year's Higher National Certificate papers in Applied Physics : the first parts of questions 7 and 9 had the same origin.

The popular questions were numbers 1, 5 and 8, and these were reasonably well answered, although the numerical solutions offered were mostly unsatisfactory.

Q. 1. The first and last parts were usually answered well, but few candidates were able to answer the middle part of the question.

Q. 2. All the answers were most unsatisfactory, and it was quite clear that the candidates did not understand either how or why a transistor works.

Q. 3. Most answers were vague and no satisfactory accounts of signal-to-noise ratio were given. The first part of the problem was not straightforward but several of those who attempted it went astray by writing $i^2 = 4kTRf$. The second part of the problem, although very simple, was attempted by only one candidate (who obtained the correct answer).

Q. 4. In view of the current interest in F.M. broadcasts, it was rather surprising that only two candidates attempted (*a*). The apparatus suggested for (*c*) was ingenious even if not very effective, but the difficulties of (*b*) seemed to pass unnoticed.

Q. 5. This was a straightforward question, answered well, but only about half the answers mentioned feedback.

Q. 6. Most of the answers to this question described d.c. amplifier circuits without explaining the reasons for their adoption.

Q.7. Several candidates made very heavy going of the first part, and only one made a reasonable attempt at the numerical example. Although it sounds difficult, this is actually quite easy if it is realized that the potential difference across a condenser cannot change instantaneously The output waveform therefore contains discontinuities of the same magnitude as the input signal.

Q.8. Only a few candidates tackled the numerical example and none with any confidence. Several correct answers were obtained, however.

Q.9. This was the least popular question, and only one reasonable answer was given.

Nuclear Instrumentation and Measurement — Mr. A. E. De Barr

The descriptive questions were, in general, well answered but none of the numerical answers was even approximately correct.

X-Rays — Mr. A. E. De Barr and Mr. R. F. Farr

With the exception of one very good paper, few of the answers showed any real understanding of the subject although most of the candidates knew something about the questions asked.

Q.1. Although most candidates showed reasonable general knowledge of the consequences of exposure to radiation, it was rather surprising to find one who did not. Unfortunately the value of the K-factor for radium was omitted from the question, and allowance had to be made for this error in assessing the performance of the candidates. (One candidate supplied the missing information herself !)

Q.2. Candidates tended to overlook the word "waveform" in this question, but otherwise most of the answers were satisfactory.

Q.4. Answers to the first part of the question were satisfactory, but candidates were not sufficiently explicit about the experimental study of the focal spot. One correct answer to the numerical part of the question was obtained.

Q.6. A large part of most answers was irrelevant. No satisfactory explanation was given of the data which referred to the absorption edge of lead and to the differing hardening effect on the X-ray beam of lead and concrete.

Q.8. In general the answers were poor. The relative rotation of crystal and detector was not even mentioned.

Q.9. This question was answered well by most candidates.

General Paper — Mr. N. Clarke

The standard was better than in previous years. Only four candidates passed but five others came fairly near the pass mark ; the remaining four were at least only poor and not pathetic. The ability of the candidates to express themselves in tolerable English was rather better than one would expect from previous experience of this examination, but most candidates find difficulty with spelling. The chief weakness, as in previous years, is, quite simply, pure ignorance.

Q.1. (13 answers) This was fairly well done, although the passage chosen was probably rather more difficult than the corresponding passages in previous papers. There were only three candidates who obviously found difficulty in understanding what the passage meant and who succeeded in putting into their own words exactly the opposite of what Herbert Butterfield wrote.

Q.2. (13 answers) Six candidates wrote on the eleven-plus examination, three on ships, three on disarmament and one on science and religion. Most of them had a fair amount to say, although not always of much substance.

Q.3. (13 answers) Perhaps it was to be expected that every candidate would attempt this. There were three good answers ; the rest were of little value for the purpose of the examination but were profoundly revealing to anyone wishing to improve his effectiveness as a teacher. Several candidates appear to have had experience of the teacher "who swots up the next day's lecture and then has to keep referring to a text-book when he gets stumped during a lecture." One candidate ended his comments on teachers with "there are other weaknesses such as, bullying, rudeness and sometimes sadism." Nor is the image of Mr. Chips conjured up by "One of the physics teachers I have had was too old for the job, was boring, long winded and kept no notes. If he had kept notes he would have been a better teacher, but taking his abilities as a whole he was a shocking teacher although he was a very nice man." Almost inevitably perhaps, someone wrote that teaching was "a vacation rather than just another job."

No one attempted question 4.

Only one candidate attempted question 5(*a*) and had exhausted his knowledge when he had recorded some quaint ideas of Conservative policy.

One candidate—significantly enough, from overseas—attempted question 5(*b*)

Q.6. (9 answers) There were three fairly good answers. *The Times*, *Manchester Guardian* and *Observer* were mainly selected as the best papers ; of the several claims to read these papers, only one carried real conviction. There was at

least a breath of honesty about " *The Times* and the *Observer* are supposed to be the best and most accurate, but look how dull they are ! Personally I read the *Daily Mirror*, mainly I suppose because it's delivered at someone else's expense." Most candidates seem to think that " several hours " are needed to read either *The Times* or the *Manchester Guardian* ; those of us who read both must do less work than we thought.

Q.7. (13 answers) A popular question, in general badly done with answers mainly in journalese. Some of the candidates may recently have written a similar essay in class on this subject as several phrases are found in a number of answers. Two answers began almost identically, one of them with " Television is turning Britains (*sic*) into a race of square eyed morons."

Practical Physics — Mr. A. E. De Barr and Mr. J. Yarwood

Once again, and despite the comments made by the examiners in previous years, half of the candidates taking the practical examination this year were unprepared. These candidates were quite incapable of wiring up and using a simple potentiometer circuit to measure small potential differences. (The excuses ranged from the all too familiar one " It is several years since I had to do anything like this " to the almost incredible " I am really a theoretical physicist.") Whilst candidates are not expected to have experience of every possible physical experiment, there are certain basic types of measurement with which every physicist should be familiar. These include potentiometer measurements, bridge measurements, measurements with a spectrometer, etc., and every candidate for this Graduateship Examination is expected, as a matter of course, to be able to make these fundamental measurements without assistance. We hope that intending candidates will take note of these remarks and that it will not be necessary to repeat them next year.

Forthcoming Institute Meetings

THE following is the List of Institute meetings so far arranged for the first half of the 1958-59 session. Members of all grades may attend any of the meetings whether or not they belong to the Branch or Group concerned. Where it is indicated that application forms are necessary early application should be made.

Date	*Place*	*Speaker*	*Title, etc.*	*Time*	*Branch or Group*
Sep. 20	**Seascale** **Calder Hall**		**Pile Physics** (All day meeting)	9.30 a.m. 5.00 p.m.	North Eastern
Further details may be obtained from the Branch Honorary Secretary. Preference will be given to members of the Branch.					
Sep. 22	**Manchester** College of Science and Technology	Prof. H. Lipson F.Inst.P., F.R.S. (*Manchester College of Science and Technology*)	**The function of a university physics department**	6.45 p.m.	Manchester and District
Sep. 24	**Isleworth**		**Visit to the Mining Research Establishment**	11.00 a.m. 4.30 p.m.	Stress Analysis
Registration is necessary and details may be obtained from the Institute.					

Date	*Place*	*Speaker*	*Title*	*Time*	*Branch or Group*
Sep. 26 and 27	**London** University College	Mr. T. H. Flowers (*Post Office Engineering Research Station, Dollis Hill*) Mr. J. H. Richards (*Mullard Research Laboratories, Salford*) Mr. D. Campbell (*Plessey Ltd., Towcester*) Mr. M. Williams, Grad.Inst.P. (*Research Laboratories, The General Electric Company Ltd., Wembley*) Dr. E. H. Rhoderick A.Inst.P. (*Services Electronics Research Laboratories, Baldock*)	Conference on **Solid state memory and switching devices**	3.00 p.m.- 6.30 p.m. Sept. 26th 10.00 a.m.- 12.30 p.m. Sept. 27th	Electronics
Oct. 1	**Ewell** Surrey County Technical College	Mr. D. H. Lucas, F.Inst.P. (*Central Electricity Research Laboratories, Leatherhead*)	**Tour of College Laboratories.** **Theory, measurement and responsibility in atmospheric pollution**	4.30 p.m. 6.15 p.m.	London and Home Counties Jointly with Ewell County Technical College Faraday Society
Oct. 8	**London** The Institute's House	Mr. A. Garratt, M.B.E., A.Inst.P. (*National Physical Laboratory, Teddington*)	**Presenting science on television**	6.00 p.m.	Education
Oct. 9	**Liverpool** The University	Dr. H. D. Parbrook, A.Inst.P. (*The University of Liverpool*)	**Acoustics research in the University of Liverpool, followed by a visit to the Acoustics Laboratories, George Holt Physics Laboratories**	7.00 p.m.	Liverpool and North Wales
Oct. 14	**London** The Institute's House	Mr. G. W. A. Dummer (*Royal Radar Establishment, Malvern*)	**"Microminiature" electronic components**	5.30 p.m.	Electronics
Oct. 15	**Newcastle upon Tyne** King's College	Prof. S. Tolansky, F.Inst.P., F.R.S. (*Royal Holloway College, Egham*)	**Optical studies on the microstructures of diamonds**	5.30 p.m.	North Eastern
Oct. 15	**Sheffield** The University	Prof. R. Pepinsky, (*Pennsylvania State University*)	**The revision of Groth's *Chemische Kristallographie***	5.30 p.m.	X-ray Analysis Jointly with the Sheffield Crystallographic Colloquium
	Yorkshire Branch members will be particularly welcome to attend this meeting.				
Oct. 17	**Cardiff** University College	Prof. E. R. Andrew, F.Inst.P., F.R.S.E. (*University College of North Wales, Bangor*)	**Nuclear magnetic resonance**	5.15 p.m.	South Wales
Oct. 17	**Bristol** The University	Dr. R. A. Smith (*Royal Radar Establishment, Malvern*)	**The use of infra-red spectroscopy in the study of semi-conductors**	7.00 p.m.	South Western

Date	*Place*	*Speaker*	*Title*	*Time*	*Branch or Group*
Oct. 17	**London** The Institute's House	*Proposers:* Mr. W. G. Cook (*Rolls Royce Ltd., Derby*) and Mr. B. D. Burns, A.Inst.P. (*Armament Research and Development Establishment, Fort Halstead*) *Opposers:* Dr. E. G. Stanford, F.Inst.P. (*Aluminium Laboratories, Ltd., Banbury*) and Mr. N. Clarke, F.Inst.P. (*Deputy Secretary, The Institute of Physics*)	**Group Annual General meeting followed by debate on the motion :— That this House considers that the Non-Destructive Testing Group serves no useful purpose**	6.00 p.m.	Non-Destructive Testing
Oct. 20	**Manchester** The University	Mr. J. Maddox (*Scientific Correspondent, Manchester Guardian*)	**Writing about science**	6.45 p.m.	Manchester and District
Oct. 20	**Edinburgh** The University	Dr. P. S. Farago (*University of Edinburgh*)	**The spinning electron**		Scottish
Oct. 21	**Glasgow** The University	Dr. P. S. Farago (*University of Edinburgh*)	**The spinning electron**		Scottish
Oct. 22	**Aberdeen** The University	Dr. P. S. Farago (*University of Edinburgh*)	**The spinning electron**		Scottish
Oct. 23	**Birmingham** Exchange and Engineering Centre	Dr. A. Gibson (*Controlled Thermonuclear Reactor Division, A.E.R.E., Harwell*)	**Thermonuclear power**	7.00 p.m.	Midland
Oct. 29	**Leeds** The University	Dr. L. Mackinnon (*University of Leeds*)	**Ultrasonics—superconductivity—liquid helium**	3.00 p.m.	Yorkshire
Oct. 31	**London** The Institute's House		**At Home.** Attendance by ticket only	7.30 p.m. to 11.00 p.m.	London and Home Counties
Nov. 6	**Bangor** University College	Prof. J. F. Allen, F.R.S. (*University of St. Andrews*)	**Liquid helium**	5.45 p.m.	Liverpool and North Wales
Nov. 10	**London** The Institute's House	Dr. N. A. de Bruyne, F.Inst.P. (*Aero Research Limited, Duxford*)	**Physics of adhesives**	6.00 p.m.	London and Home Counties
Nov. 10	**Edinburgh** The University	Prof. E. G. Cullwick (*Queen's College, Dundee*)	**The riddle of relativity**	7.15 p.m.	Scottish
Nov. 11	**Glasgow** The University	Prof. E. G. Cullwick (*Queen's College, Dundee*)	**The riddle of relativity**	7.15 p.m.	Scottish
Nov. 12	**Durham** Science Laboratories	Dr. L. Essen (*National Physical Laboratory, Teddington*)	**Astronomical and atomic time**	5.00 p.m.	North Eastern
Nov. 13	**Liverpool** The University	Four speakers from industry	Discussion on **The physicist in industry**	4.00 p.m.	Liverpool and North Wales

Date	*Place*	*Speaker*	*Title*	*Time*	*Branch or Group*
Nov. 14	**London** The Institute's House		**Group Annual General Meeting. Papers on the Spectroscopy of high temperature plasma**	To be announced	Applied Spectroscopy
Nov. 14	**Manchester** College of Science and Technology	Dr. L. R. G. Treloar, F.Inst.P. (*British Rayon Research Association*)	**The photoelastic properties of polymers**	6.45 p.m.	Non-Destructive Testing—Jointly with Manchester and District
Nov. 14	**Cardiff** University College	Dr. J. W. Mitchell, F.R.S. (*University of Bristol*)	**Photographic sensitivity**	5.15 p.m.	South Wales
Nov. 14	**Cheltenham** N. Gloucestershire Technical College	Mr. E. W. H. Selwyn, F.R.P.S., F.Inst.P. (*Kodak Limited, Harrow*)	**Definition in photographs**	7.00 p.m.	South Western
Nov. 18	**London** The Institute's House	Dr. M. H. Oliver, (*Royal Radar Establishment, Malvern*)	**Masers**	5.30 p.m.	Electronics
Nov. 19	**London** The Institute's House	Dr. K. A. G. Mendelssohn, F.Inst.P., F.R.S. (*Clarendon Laboratory, University of Oxford*)	**Planck and his work—Celebration of the centenary of the birth of Max Planck**	6.00 p.m.	Education
Nov. 21	**Glasgow** The University	Dr. S. C. Curran, F.R.S. (*Atomic Weapons Research Establishment, Aldermaston*)	**Controlled thermonuclear work**	7.15 p.m.	Scottish
Nov. 24	**Edinburgh** The University	Dr. S. C. Curran, F.R.S. (*Atomic Weapons Research Establishment, Aldermaston*)	**Controlled thermonuclear work**	7.15 p.m.	Scottish
Nov. 25	**Birmingham** Exchange and Engineering Centre	Dr. R. E. Bastick A.Inst.P. (*Chance Brothers Ltd., Smethwick*)	**Branch Annual General Meeting. Chairman's address on —Some applications of glass in the field of atomic energy**	7.00 p.m.	Midland
Nov. 26	**Sheffield** The University	Dr. B. J. Mason (*Imperial College of Science and Technology, London*)	**Recent developments in the physics of rain and rain making**	5.15 p.m.	Yorkshire
Nov. 27	**London** Royal Society of Arts		**Group Annual General Meeting and all-day meeting**		Electron Microscopy
			Electron Staining : Reviews on papers presented at the International Conference on Electron Microscopy (Berlin, Sept. 1958)	To be announced	
Nov. 28	**London** Institution of Civil Engineers		**Autumn Conference Precipitation in alloys**	10.00 a.m. 5.00 p.m.	X-Ray Analysis —Jointly with Electron Microscopy
Nov. 29	**London** Institution of Civil Engineers		**Autumn Conference** (continued) **Metals**	9.30 a.m.- 12.30 p.m.	X-Ray Analysis

Date	*Place*	*Speaker*	*Title*	*Time*	*Branch or Group*
Dec. 1	**Edinburgh** The University	Dr. B. Meltzer (*University of Edinburgh*)	**Dense electron beams**	7.15 p.m.	Scottish
Dec. 2	**Glasgow** The University	Dr. B. Meltzer (*University of Edinburgh*)	**Dense electron beams**	7.15 p.m.	Scottish
Dec. 3	**London** The Institute's House	Prof. H. Hartridge, F.R.S.	**Transparency projection**	6.00 p.m.	Education
Dec. 8	**Glasgow** The University	Mr. A. D. Le Claire (*U.K. Atomic Energy Authority, Harwell*)	To be announced	7.15 p.m.	Scottish
Dec. 9	**Aberdeen** The University	Mr. A. D. Le Claire (*U.K. Atomic Energy Authority, Harwell*)	To be announced	7.30 p.m.	Scottish
Dec. 11	**Liverpool** The University	Mr. R. S. Pease (*U.K. Atomic Energy Authority, Harwell*)	**Thermonuclear power**	7.00 p.m.	Liverpool and North Wales
Dec. 11	**London** The Institute's House	Dr. G. D. Robinson, F.Inst.P. (*Meteorological Office, Air Ministry, London*)	**Exploring the vertical structure of the atmosphere**	6.00 p.m.	London and Home Counties
Dec. 11	**Birmingham** Imperial Chemical Industries Limited	Dr. T. W. Farthing (*New Metals Section, I.C.I. Research Department, Metals Division, Witton, Birmingham*)	**Visit to the Metals Division of Imperial Chemical Industries Ltd. followed by Lecture on New metals** — numbers limited	2.30 p.m.	Midland
Dec. 11	**Middlesbrough** Cleveland Scientific and Technical Institution	Dr. A. W. Brewer, F.Inst.P. (*Clarendon Laboratory, University of Oxford*)	**Instruments used in the exploration of the stratosphere**	6.00 p.m.	North Eastern—Jointly with Society of Instrument Technology
Dec. 12	**London** The Institute's House	Dr. J. Krautkramer (*J. & H. Krautkramer, Cologne*)	**Ultrasonic developments**	6.00 p.m.	Non-Destructive Testing
Dec. 12	**Swansea** University College	Dr. W. Walkinshaw (*U.K. Atomic Energy Authority, Harwell*)	**Branch Annual General Meeting. High energy particle accelerators**	5.15 p.m.	South Wales
Dec. 12	**Bristol** The University	Dr. R. M. Payne (*Associated Electrical Industries Research Laboratory, Aldermaston*)	**The quest for controlled thermonuclear reactors**	7.00 p.m.	South Western
Dec. 15	**Manchester** The University	Dr. E. B. Mendoza (*University of Manchester*)	**Electronic applications of superconductors**	6.45 p.m.	Manchester and District
Dec. 16	**London** The Institute's House	Prof. K. W. H. Stevens (*University of Nottingham*)	**Ferromagnetic microwave amplifiers**	5.30 p.m.	Electronics

Date	*Place*	*Speaker*	*Title*	*Time*	*Branch or Group*
1959					
Jan. 8	**Liverpool** The University	Prof. J. Rotblat, F.Inst.P. (*St. Bartholomew's Hospital, London*)	**Biological hazards of radiation**	7.00 p.m.	Liverpool and North Wales
Jan. 14	**London**	The President of the Institute, Sir George Thomson, Hon.F.Inst.P., F.R.S. (*University of Cambridge*)	Place, time and title of lecture to be announced		London and Home Counties
		All members of the Institute and guests will be welcomed			
Jan. 16	**Bristol** The University	Prof. F. W. Spiers (*University of Leeds*)	**Biological hazards of radiation**	7.00 p.m.	South Western
Jan. 16	**London**	Mr. S. Rees Jones, F.Inst.P. (*Courtauld Institute of Art, London*)	**Group Dinner Meeting followed by— Testing of works of art and the detection of forgeries**	Time and place to be announced	Non-Destructive Testing
		Limited to Institute members and ladies only.			
Jan. 19	**Manchester** The University	Prof. R. W. Ditchburn, F.Inst.P. (*University of Reading*)	**Eye movements and visual perception**	6.45 p.m.	Manchester and District
Jan. 20	**Gosta Green** Birmingham College of Technology	The President of the Institute, Sir George Thomson, Hon.F.Inst.P., F.R.S. (*University of Cambridge*)	**Sir J. J. Thomson**	7.00 p.m.	Midland
Jan. 21	**London** The Institute's House	Dr. J. Topping, F.Inst.P. (*Brunel College of Technology, Acton*) Prof. A. J. Woodall, O.B.E., F.Inst.P. (*Royal Military College of Science, Shrivenham*)	**A discussion on scientific method**	6.00 p.m.	Education
Jan. 22 & 23	In conjunction with the British Nuclear Energy Conference		**Symposium on Nuclear Fuel Cycles**		
		Application forms from the Secretary of the Institute			

The Institute's Journals

PRINCIPAL CONTENTS OF THE SEPTEMBER, 1958, ISSUES

Journal of Scientific Instruments: Volume 35, No. 9

ORIGINAL CONTRIBUTIONS

A calculator for numerical Fourier synthesis. By V. Timbrell.

The customary numerical method of Fourier synthesis using three figure tables, is accurate but laborious and slow. The calculator described makes the method ten times faster, and the accuracy is about the same. It is especially useful for the occasional synthesis which does not justify an automatic machine.

For each of twelve harmonics, expressed in the form $R_k \sin(\varphi_k + k\theta)$, numerical values are obtained for $\theta = 0°, 7\frac{1}{2}°, 15°, \ldots 352\frac{1}{2}°$. These are recorded on a work-sheet and the sum $\sum_{k=1}^{k=12} R_k \sin(\varphi_k + k\theta)$ is got by simple addition for each value of θ. The principle is applicable to any values of k and any of the commonly used intervals of θ. Full use is made of the frequent recurrence of values for some harmonics in order to minimize the number of readings that must be taken from the calculator.

A mechanical Fourier synthesizer of simple construction for handling fifteen harmonics is described in an appendix. This instrument enables the synthesized waveform to be plotted directly.

A microwave spectrometer for the study of free radicals. By I. R. Hurle, Grad.Inst.P., and T. M. Sugden.

A microwave spectrometer suitable for the study of short-lived molecules in the gas phase, in particular free radicals, has been constructed to operate over a frequency range from about 20 to 70 kMc/s. An innovation is the use of surface wave propagation of the microwaves along a wire in the absorption cell, a system which has very wide band-pass properties. High sensitivity is obtained by using a radio-frequency modulation of the klystron source. The apparatus is described in detail, with some account of the underlying principles, and preliminary results with the short-lived substance carbon monosulphide are presented.

X-ray absorption microanalysis with fine-focus tubes. By J. V. P. Long.

A point focus X-ray tube has been used as a source for microanalysis by the X-ray absorption method. Transmission measurements on selected specimen areas of 2–10μ diameter are possible, with wavelengths chosen by a crystal and a proportional counter. Comparison of the transmitted intensities at different wavelengths gives quantitative information on the mass thickness of elements present in the area examined. The ultimate mass sensitivity varies with the position of the element in the periodic table but is usually in the range 10^{-10}–10^{-12} g for elements of $Z > 15$. The application of the method to the determination of calcium is described.

An airborne infra-red solar spectrometer. By J. T. Houghton, T. S. Moss and J. P. Chamberlain.

A grating spectrometer developed for installation in a Canberra aircraft is described. An electronically operated heliostat maintains an image of the sun on the entrance slit. Resolution of 2 cm^{-1} is achieved with a lead sulphide detector. Preliminary results are given for the 2μ region for heights up to 45,000 ft.

The influence of rate of cooling on the zeros of mercury-in-glass thermometers. By Sj. van Dijk, J. A. Hall, F.Inst.P., and Vera M. Leaver.

A study of the effect of rate of cooling on the temporary depression of the zero of high-range mercury thermometers has been made from two points of view. It is concluded that if the cooling rate is sufficiently slow (about 15 h to cool from 400° C to room temperature) the temporary depression is completely suppressed. It is also concluded that from the point of view of a "permanence of range" or "bulb stability" test, the best discrimination between different batches of thermometers is obtained when the zeros are determined after slow cooling.

A method of flash synchronization for high-speed cinematography. By J. D. Lewis and G. T. Peck.

A description is given of the method used to synchronize a high-power stroboscope for use as the light source for high-speed cinematography. The essential requirements which had to be met were that the camera modifications should be kept to a minimum and that the synchronization should be effective over a speed range from 200 to 8,000 frames/s.

A vibration pick-up which does not load the system being examined. By S. K. Rushforth and A. Selwood, Grad.Inst.P.

The present device measures the amplitude, and indicates the phase of vibration of a structure without touching or loading it in any way. The transducer may be positioned anywhere adjacent to the surface of the structure so as to measure its amplitude of vibration at any given point. The apparatus is only suitable for the measurement of continuous simple harmonic oscillation such as appear in resonance testing.

A moving coil vibrator is held close to the structure and is electrically driven so that the vibrator oscillates in sympathy with the structure. This sympathy of movement is detected by measuring the electrical capacitance between two plates, one formed by the structure itself, and one mounted at the tip of the vibrator shaft. The amplitude and phase of the

current which drives the vibrator are adjusted until this capacitance becomes constant. The vibrator then moves with the same amplitude and phase as the structure and any type of vibration amplitude pick-up may be permanently fixed to the vibrator shaft. Whatever mechanical power is absorbed by this measuring pick-up comes from the supply to the vibrator and not from the structure itself.

In the present apparatus, used for resonance testing a small wind-tunnel model, vibration amplitudes up to 0·030 in. may be measured with good linearity and reproducibility, with a resolution of about 0·0001 in. It is essnetial that the structure under examination be metallic, or, if not, covered with an electrically conducting layer.

A permeameter controller for magnetic measurements. By M. J. Swan.

Determinations of the magnetic properties of materials by the ballistic method often involves complicated switching of the magnetizing currents. A semi-automatic controller has been built which carries out the switching operations and ensures the material is maintained in a cyclic magnetic state. The N.P.L. permeameter is also briefly described.

A piezo-electric pressure bar gauge. By D. H. Edwards.

A pressure bar gauge is described in which the average stress over the cross-section of the bar is measured by means of an X-cut quartz disk. Bars of duralumin and lead are employed since the acoustic impedances of these materials closely match the value appropriate to longitudinal thickness vibrations in the quartz. The design of a gauge housing, suitable for mounting in the wall of an explosion or shock tube, is discussed.

British Journal of Applied Physics: Volume 9, No. 9

SPECIAL ARTICLE

The physics of fibres with special reference to wool.* By A. B. D. Cassie, C.B.E., F.Inst.P.

There are many angles from which one could approach the physical study of fibrous materials. In the book under a similar title published in the Physics in Industry series Woods has dealt largely, but not exclusively, with those aspects of the study which are concerned with the consequences of the molecular structure of fibrous substances. On the other hand, there are many interesting physical problems, particularly in relation to fibre assemblies such as fabrics, which arise purely from the geometrical form of the fibres and their ability to exchange water vapour with the atmosphere. This paper is largely concerned with these aspects of the subject.

* Based on a lecture given to the North Eastern Branch of The Institute of Physics in Newcastle upon Tyne on December 4, 1957.

ORIGINAL CONTRIBUTIONS

Some developments and applications of micro-focus X-ray diffraction techniques. By A. Franks.

This paper describes a low angle X-ray scattering camera, a microbeam camera and an electron gun for a microfocus X-ray tube. In the low angle scattering camera which can resolve a spacing of 1,000 Å using CuK radiation, the X-ray beam is totally reflected by two crossed bent glass plates, which focus the relatively intense beam on to a small spot on the film. Provision is made for accurately positioning a selected area of the specimen in the path of the beam. This facility is also provided in the microbeam camera for transmission and back reflexion work. In the electron gun, focusing is facilitated by independent adjustments of the positions of the filament and grid cylinder, while the tube is in operation.

Temperature distribution throughout a stack of electrical sheet steel during annealing. By R. J. Wakelin, A.Inst.P.

During the final annealing process in the manufacture of 4% silicon-iron electrical sheet, the temperature at any one time varies horizontally across the plane of the sheets and vertically up the stack. The temperature distribution in the horizontal plane of sheets 8 ft. × 3 ft. × 0·014 in. thick has been calculated theoretically and compared with that determined experimentally. By combining the results from a number of experiments, the temperature distribution throughout a stack of sheets has been obtained at all times during the three-day annealing cycle.

Heat-reflecting windows using gold and bismuth oxide films. By L. Holland, F.Inst.P. and G. Siddall.

Thin gold films sandwiched between certain metal oxide layers possess a high electrical conductivity and high optical transparency. They also have a high infra-red reflectance, and may be used as transparent heat-reflecting coatings if their yellowish tinted-colour in transmitted light can be tolerated. The observation window of an enclosure exposed to infra-red radiation was coated with different film combinations, and their effectiveness in reducing the internal temperature rise determined. The reflectance and transmittance of the coatings were measured at $\lambda = 0{\cdot}56\mu$ and in the infra-red region using a photometer with a broad bandwidth ($0{\cdot}8 - 2\mu$). Results are given for the following: plain glass; a high reflecting bismuth oxide film on glass; gold film on glass; and gold films sandwiched between bismuth oxide and silicon monoxide coatings. Optimum performance was obtained with a $Bi_2O_3/Au/Bi_2O_3$ multi-layer of 450/130/450Å thickness which had a transmittance of 73% for green light and a reflectance of 74% in the

near infra-red region, compared with values of 55 and 35% respectively for a gold film of the same thickness without the oxide layers.

A general scheme for the examination of precipitates and inclusions in steels*. By G. R. Booker, A.Inst.P., and J. Norbury, F.Inst.P.

A comprehensive scheme is described for the examination of included materials occurring in steels using the newer physical techniques. The material is isolated by extraction replicas in a form suitable for examination by optical and electron microscopy, electron and X-ray diffraction, and X-ray fluorescent and spectrographic analysis.

Application of the scheme allows the precise form and identity of the included material to be determined, even when only small amounts of specimen are available. The extraction replica method enables particles up to about 50μ and less than 0·01μ in size to be satisfactorily isolated and retained for examination. The possibility of modification of the included material during isolation is small because only mild chemical treatments are used. The scheme has been satisfactorily applied so far to iron and alloy carbides and nitrides, and simple and mixed oxides and sulphides present in steels.

* This paper was presented at the Annual Conference of the Electron Miscroscopy Group of The Institute of Physics held in Bangor, September, 1957.

The performance of bismuth telluride thermojunctions. By H. J. Goldsmid, A. R. Sheard and D. A. Wright, F.Inst.P.

The thermoelectric properties of *n*-type and *p*-type bismuth telluride between 150 and 300° K have been measured and the figure of merit for thermoelectric applications has been calculated. This figure of merit has been shown to be highest for material with an electrical conductivity of about 1,000 Ω^{-1} cm^{-1} with current flow parallel to the cleavage planes. Its value at 290° K corresponds to a maximum cooling by means of the Peltier effect of about 65° C, and an efficiency of thermoelectric generation of 1% for a 25° C temperature difference.

The flow of heat in a parallel-faced infinite solid. By T. P. Newcomb, A.Inst.P.

A solution is given for the problem of heat conduction in an infinite slab in which one face is subjected to a linearly decreasing thermal flux $Q(1 - at)$, there being no flow of heat at the parallel boundary. This solution may be applied to the problem of braking with uniform deceleration. Typical curves illustrating the agreement between transient temperatures determined theoretically and experimentally at different points in the slab are given.

Studies of the viscosity and sedimentation of suspensions. Part 4.—Capillary-tube viscometry applied to stable suspensions of spherical particles*. By G. H. Higginbotham, D. R. Oliver and Prof. S. G. Ward.

A description is given of a series of measurements of the viscosity of stable suspensions of spherical particles in an efflux-type capillary-tube viscometer.

It is shown that a form of wall-effect is present in the tube, which causes the apparent viscosity of the suspensions to decrease with decreasing tube-size. The suspensions are shown to behave as though a layer of pure liquid were present along the tube walls, though the layer appears to be only hypothetical in nature. The values of the wall-layer thickness obtained in the present work are used in a brief assessment of a recently-proposed " concentration " theory of wall effect.

The final values of the relative viscosity, corrected for wall effect, show no dependence on absolute particle size or particle size-range. All series of results are shown to be governed by a single type of equation, which reduces to that of Einstein at very low values of the volume concentration.

* Parts 1 and 2 of this paper, " The viscosity of suspensions of spherical particles " and " The viscosity and sedimentation of suspensions of rough powders," were published on pp. 286 and 325 of Volume 1 (1950) of this Journal. Part 3, " The sedimentation of isometric and compact particles," was published on p. 83 of Volume 6 (1955) of this Journal.

Energy balance in disk seal oscillators at ultra-high frequencies. By M. R. Gavin and L. J. Herbst.

Energy measurements were made on DET 22 (CV273) disk seal triode oscillators in the frequency range 500–2,000 Mc/s. It was found that most of the input power from the d.c. supplies could be accounted for by the a.c. output power and the power dissipated at the electrodes, including the heating of the cathode coating by h.f. currents.

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DIVISION OF ELECTROTECHNOLOGY

APPOINTMENT OF PHYSICISTS

Applications are invited for appointment to one of two positions of physicist with the organization's division of Electrotechnology. The division, comprising a staff of forty scientists and thirty ancillary staff is located in the University Grounds, Sydney, and is engaged in research in the field of electrical standards of measurement and allied subjects such as dielectrics research and microwave spectroscopy.

The two positions available are :—

(*a*) Dielectrics research. The appointee will be a member of a group of seven scientists engaged in dielectrics research. Adequate opportunity will be available for the appointee to develop an individual research programme. Applicants should possess a University honours degree in physics and some post-graduate research experience. Experience in some branch of solid state physics would be desirable.

(*b*) Radio frequency measurements. Initially the appointee would be engaged on research in the frequency range 200 to 2,000 Mc/s to develop precise power measuring techniques in the very low power range. However, ample opportunities will be given for the appointee to develop an individual research programme in precise radio frequency measurements or an allied field. Applicants should hold a University honours degree in physics with postgraduate research experience.

Dependent upon qualifications and experience, commencing salary for each position will be determined within the salary ranges of Research Officer, £A1,326–£A1,951 p.a. or Senior Research Officer, £A2,061–£A2,336 p.a. Salary for a female appointee would be £170 p.a. less than the corresponding male rates.

Appointment will be conditional upon a satisfactory medical examination.

The Appointments will be for an indefinite period or for a period of three years, at the option of the appointees. Confirmation of appointment for an indefinite period carries with it Commonwealth Superannuation Fund or Commonwealth Provident Account privileges.

Fares to Australia, including those of wife and dependent family, will be provided by the organization, and, in the case of appointment for a fixed period, return fares to point of origin will be allowed for an appointee who is not of Australian nationality. Details may be discussed with the undersigned.

Applications quoting Appointment No. 760/106 and stating full name, place, date and year of birth, nationality, marital state, present employment, details of qualifications and experience and of war service if any, together with the names of not more than four persons acquainted with the applicant's academic and professional standing, should reach the undersigned, from whom further particulars may be obtained, by September 26, 1958.

E. J. Drake,
Chief Scientific Liaison Officer.

Australian Scientific Liaison Office,
Africa House,
Kingsway, London, W.C.2.

MATHEMATICAL/PHYSICIST

PLESSEY NUCLEONICS LTD. have a vacancy for a mathematical/physicist to analyse problems concerning the control and operation of nuclear reactors. The successful applicant should have a degree in physics or mathematics, and an absorbing interest in the application of mathematical methods to a variety of problems, as for example, information theory and statistics, diffusion theory, shielding calculations, functions of a complex variable or servo-analysis.

This post offers considerable scope for original work for which a generous salary is envisaged, depending upon qualifications and experience. Please send full particulars, which will be treated in confidence, to the Personnel Department, Plessey Nucleonics Ltd., Weedon Road, Northampton.

AUSTRALIA—
UNIVERSITY OF NEW ENGLAND

LECTURESHIP IN PHYSICS
SENIOR LECTURESHIP OR SENIOR RESEARCH FELLOWSHIP IN THEORETICAL PHYSICS

Applications are invited for the following positions :—

(*a*) Lecturer in Physics: Salary according to qualifications and experience within the range £A1,500 × £90–£2,050 plus cost of living allowance.

(*b*) Senior Lectureship or Senior Research Fellow in Theoretical Physics : A senior lectureship is a permanent appointment with a salary range of £A2,200 × £80–£2,500 plus cost of living allowance. A senior lecturer takes a normal part in the teaching programme of the Department. A senior research fellowship is a temporary appointment made initially for three years and extendable to five. The salary is fixed within the range for senior lecturers without increments. A senior research fellow may give some lectures at honours or postgraduate level.

A person appointed to either position would be expected to undertake a program of theoretical research, preferably, but not necessarily, in the fields of ionization and discharge physics, ionospheric physics or solid state physics.

GENERAL INFORMATION

Senior lecturers and lecturers are required to contribute to the State Superannuation Fund of New South Wales. A senior research fellow is not eligible for superannuation. Provision is made for travel and removal expenses and assistance in buying or building a home.

Further information and the conditions of appointment may be obtained from the Secretary, Association of Universities of the British Commonwealth, 36 Gordon Square, London, W.C.1.

Applications will close in London and Australia, on November 28, 1958.

GLOUCESTER TECHNICAL COLLEGE

DEPARTMENT OF SCIENCE

A LECTURER IN PHYSICS, able to teach up to B.Sc. General and Grad.Inst.P. standard, is required from September 1, 1958, or as soon as possible thereafter. The person appointed will be responsible, under the direction of the head of department, for the work in physics. The salary will be in accordance with the Burnham scale for Lecturers, viz. £1,200 × £30 – £1,350. Application forms and further particulars may be obtained from the Principal, Technical College, Brunswick Road, Gloucester, to whom completed forms should be returned as soon as possible.

THE MANCHESTER COLLEGE OF SCIENCE AND TECHNOLOGY

(FACULTY OF TECHNOLOGY IN THE UNIVERSITY OF MANCHESTER)

APPOINTMENT OF RESEARCH ASSISTANT

Applications are invited for the post of research assistant in the Department of physics. The person appointed will be required to take part in the research of the department which is at present concerned with X-ray diffraction, physical optics, electronics and instrumentation, and will be expected to become a candidate for the degree of Ph.D. Applicants should, therefore, have a good honours degree in physics and some research experience, not necessarily related to the subjects mentioned above.

Salary scale : £575 × £25–£600 per annum.

Superannuation under the F.S.S.U. Family allowances.

Forms of application may be obtained from The Registrar, The Manchester College of Science and Technology, Manchester, 1, to whom they should be returned not later than September 20, 1958.

THE COLLEGE OF AERONAUTICS

DEMONSTRATOR IN METALLURGY OR MATERIALS required to assist in the organization of laboratory teaching. Opportunities exist for lecturing and there are good facilities for research. Candidates should possess a degree or equivalent qualifications in Metallurgy or a related science such as physics. Experience in metal technology an advantage. Subsequent promotion to lecturer grade possible if suitably qualified. Salary within scale £600 × £25–£900 × £25–£1,000 per annum, dependent on qualifications and experience, with superannuation under F.S.S.U. and family allowance.

Applications giving full particulars and containing the names of three referees, to the Recorder, The College of Aeronautics, Cranfield, Bletchley, Bucks. Further particulars available.

GOVERNMENT OF NORTHERN RHODESIA

EXPERIENCED ELECTRON MICROSCOPIST required in Mines Department to undertake preparation of samples for electron microscopic investigation; electron microscopic study of fine dust particles, ultra-thin tissue sections, etc., and maintenance of the instrument in good working order. Candidates should have had at least three years' experience in electron microscopy with experience in electronics, high vacuum technique and scientific photography. The microscope is a Phillips instrument (large model). Brief training for the particular instrument would be arranged if necessary.

Appointment on permanent basis with pension or short term contract with gratuity. Salary scale is £990 to £1,950 a year; starting salary will be assessed according to age and experience. Free passages provided in both directions for officer and wife and assisted passages for children. Housing with heavy furniture provided at low rental. Income tax at low rates and generous home leave granted after each tour of service. Tours are from 2 to 3 years.

Application forms and further particulars from Director of Recruitment, Colonial Office, London, S.W.1 (quoting BCD 99/3/08).

ENGLISH ELECTRIC VALVE CO. LTD.

Chelmsford, Essex

CAMERA TUBE RESEARCH

Applications are invited from men with a Ph.D. or good Honours Degree who would like to join a new research team working on Television Camera Tubes and other Photo-electronic devices. Experience in this field is not essential but candidates must have a sound basic knowledge of photoconductivity, solid state physics or physical chemistry. Practical experience in these fields, or in vacuum technology would be valuable.

Please write giving full details to Department C.P.S., Marconi House, Strand, London, W.C.2 quoting reference PB1506Q

PHYSICIST required for work both on site and in the laboratories of the Atomic Energy Division of The General Electric Co. Ltd. at Erith. The work will include both experimental work on reactor shielding and low background radioactive counting in relation to district survey work. Any experience of the relevant techniques will be advantageous but not essential if applicant has suitable academic qualifications. The position offers an excellent opportunity for a young man interested in entering a new and rapidly expanding industry. Apply giving age and details of training and experience to Personnel Manager (JDA), The General Electric Co. Ltd., Erith, Kent.

RESEARCH PHYSICIST

COURTAULDS LIMITED has an interesting vacancy for a physicist in one of its Coventry Research Laboratories. Initially the work will be concerned with the physical and mechanical properties of industrial man-made fibres, but this will lead to more varied problems offering wide scope to a versatile man.

Qualifications required : First or Second Class Honours degree or Graduate of The Institute of Physics. Age under 28. Two or three years industrial or research experience an advantage.

Candidates should write for a detailed form of application to the Director of Personnel, Courtaulds Ltd., 16 St. Martins-le-Grand, London, E.C.1, quoting reference number D.88.

Appointments Vacant

The inclusion of particulars of a vacancy must not be taken to imply that the Institute necessarily approves of the terms offered or that might be offered. Candidates should satisfy themselves that these are satisfactory, and they may always refer to the Institute for advice.

PHYSICS GRADUATE required for a materials research laboratory situated in South Northants. Applicants should preferably have had some experience in the measurement of the properties of materials at liquid hydrogen/helium temperatures, or alternatively of the properties of semi-conductors. Please apply to the Deputy Research Manager, The Plessey Co. Ltd., Caswell, Towcester, Northants.

UNIVERSITY OF LONDON
ROYAL HOLLOWAY COLLEGE
RESEARCH ASSISTANT IN PHYSICS

Applications are invited for the post of senior research assistant for a program of work on the magnetic properties of thin films. The appointment is tenable from October 1, 1958, and is for two years in the first instance. Applicants should be of Ph.D. standard ; some experience of electronics and/or low temperature work is desirable although not essential. The salary will be up to £900 per annum with F.S.S.U. benefits if required.

Applications, which should include a statement of qualifications and the names of not more than three persons to whom reference may be made, should be sent to the Principal, Royal Holloway College (University of London), Englefield Green, Surrey, as soon as possible.

ESSEX EDUCATION COMMITTEE
MID-ESSEX TECHNICAL COLLEGE
MARKET ROAD, CHELMSFORD

The following teachers are required in the Science Department from January 1959 :

(*a*) SENIOR LECTURER IN APPLIED PHYSICS. Candidates should hold a good honours or higher degree, be corporate members of The Institute of Physics, and having teaching as well as industrial and/or research experience. Salary scale : £1,350 × £50 – £1,550 per annum.

(*b*) LECTURER IN PHYSICS. Candidates should have a good Honours Degree or equivalent, together with teaching, research, or industrial experience, and be able to offer specialized knowledge of a branch of applied physics. Salary scale : £1,200 × £30 – £1,350 per annum.

Details and application forms (stamped addressed foolscap envelope) from the Clerk to the Governors at the College.

MAGNETOHYDRODYNAMICS IN CANADA

We have a challenging position for a mathematical physicist with a good honours degree who would be interested in doing research in the general field of magnetohydrodynamics. This is a government sponsored project with an excellent salary available for the right man and could be an opportunity leading to a fine career in Canada.

If you are interested, write by air mail giving full details of qualifications and experience to A. J. Langley, F.Inst.P., Industrial Relations Manager, Computing Devices of Canada Ltd., Box 508, Ottawa, Canada.

PILKINGTON BROTHERS LTD.

MATHEMATICIAN STATISTICIAN

with a good honours degree in mathematics, appropriate experience and necessary personality to lead a section of the rapidly expanding Central Research Department.

The work of the section includes the application of mathematical and statistical methods to production and research problems in all aspects of Glass manufacture.

GRADUATE PHYSICIST

with subsidiary mathematics and chemistry and experience of environmental physics in relation to heat, light and sound in building, to lead a section of the Products Application Department.

Apply stating age, qualifications, experience and present salary to Personnel Officer (Graduate Recruitment), Pilkington Brothers Ltd., St. Helens, Lancashire.

IMPERIAL COLLEGE OF SCIENCE AND TECHNOLOGY
LONDON, S.W.7

RESEARCH PHYSICIST or ENGINEER, preferably with knowledge and aptitude for hydrodynamics, required to undertake model research on fluid flow. Work could lead to higher degree. Salary £450 – £850 per annum, according to experience. Apply, with names of two referees, to Meteorology Department.

UNIVERSITY OF READING

Applications are invited for a senior appointment as research physicist in the Department of Physics. The work will involve electrical measurements applied to the study of surface contamination processes on semiconductors. Experience in the use of ultra-high vacuum systems or in the chemical physics of surfaces is desirable. Salary according to qualifications and experience. Further particulars may be obtained from the Professor of Physics, University of Reading, Physics Research Laboratories, Upper Redlands Road, Reading, Berks, to whom applications should be submitted as soon as possible and not later than October 24, 1958.

THE COLLEGE OF AERONAUTICS

LECTURER and DEMONSTRATORS required in Metallurgy or the materials sciences, to teach at postgraduate level in specialized fields. There is a particular requirement for specialists in non-metallic materials or in metal technology, but other branches are relevant. Good facilities exist for research and publication is encouraged. Demonstrators must be academically qualified and will, if suitable, be considered for subsequent promotion to lecturer. A housing scheme is in operation at the college. Salary within scales : Lecturer : £900 × £50 – £1,350 × £75 – £1,650 ; Demonstrator : £650 × £25 – £1,000 ; with F.S.S.U. and family allowances. Applications including names of three referees to : Recorder, The College of Aeronautics, Cranfield, Bletchley, Bucks. Further particulars available.

The Distillers Company Ltd.

PHYSICAL CHEMIST OR PHYSICIST

The company has a vacancy at the Central Research and Development Department, Epsom, Surrey, for a physical chemist or a physicist to undertake instrumentation work. Candidates, aged not over 32 years, must hold a good degree in physical chemistry or physics, or an equivalent qualification, coupled with a sound knowledge of fundamental physical principles ; some knowledge of electronics would be an advantage, but a detailed knowledge is not required.

The successful candidate will devise, develop, test and assess new instruments for chemical laboratories and plant. Thus, following discussions with chemists and chemical engineers, he will formulate the true problem and hence the requirements of a suitable instrument ; he will then suggest principles on which the instrument might be based and examine them critically. Following this he will work with other members of the instrumentation section, including engineers, electronic engineers and physicists, on the construction of a prototype and on testing and assessing it under laboratory and plant conditions.

Salary according to qualifications and experience ; non-contributory pension scheme.

Write Staff Manager, The Distillers Company Ltd., 21 St. James's Square, London, S.W.1. Quote ref. 73/58/B.

MIDDLESEX COUNTY COUNCIL EDUCATION COMMITTEE

BRUNEL COLLEGE OF TECHNOLOGY

WOODLANDS AVENUE, ACTON, W.3

There are the following three vacancies for lecturers at the college, each post being within the Burnham Scale range £1,236 to £1,398 per annum.

1. LECTURER IN SPECTROSCOPY to teach the subject in courses for the Diploma in technology. Degree and professional qualifications necessary, and the person appointed may be required to give assistance with the teaching of physical chemistry. Ability to advise research students in the use of spectroscopic techniques desirable.

2. LECTURERS IN ELECTRONICS (2 posts) in the department of electronics to teach the subject in its physical and applied aspects. The department is responsible for the teaching of electronics throughout the college. A good understanding of the fundamentals of electronics ; industrial or research experience is necessary and university or technical college experience desirable but not essential.

The college, which occupies very pleasant modern buildings, is new and developing rapidly ; it offers courses for the diploma in technology, University of London degrees and other qualifications. There are many interesting educational problems associated with its new courses. Close contact is maintained with industry and with major research organizations, and every encouragement is given to the staff to undertake research.

Those interested in the above posts should write at once to the Principal.

C. E. GURR, M.Sc., Ph.D.,
Clerk to the Governing Body.

RICHARD THOMAS AND BALDWINS LTD.

CENTRAL RESEARCH LABORATORIES

Applications are invited from

PHYSICISTS

looking for interesting and responsible posts, who would like to join a young and enthusiastic group engaged in the application of the newer physical techniques to both long and short term investigations in steelmaking, processing and instrumentation. Present activities, in which originality and inventiveness are encouraged, cover a wide field.

Applicants should be of degree or equivalent standard, but previous experience is not essential. Commencing salaries depend on age, qualifications and experience, with good prospects.

Apply, giving full details of qualifications and experience to the Director of Research, Central Research Laboratories, Whitchurch, Aylesbury, Bucks.

RICHARD THOMAS AND BALDWINS LTD.

CENTRAL RESEARCH LABORATORIES

There are vacancies in the

PHYSICS DEPARTMENT FOR ASSISTANTS

The duties are of a wide nature covering many aspects of steelmaking and steel processing research.

Applicants should have reached a standard of education sufficient to allow them to pursue a course of part-time study leading to a professional qualification and should have the enthusiasm and keenness to achieve that end. Part-time further education is encouraged and excellent educational facilities are granted.

Salaries are on a generous scale.

Please apply to the Director of Research, Central Research Laboratories, Whitchurch, Aylesbury, Bucks.

SUNDERLAND EDUCATION AUTHORITY

SUNDERLAND TECHNICAL COLLEGE

Lecturer required in the Physics Department to teach some branch of Applied Physics to Higher National Certificate or Diploma in Technology level. Salary: Burnham (Technical) Scale for Lecturers £1,200 × £30 – £1,350 (allowances for industrial experience in approved cases).

Particulars from the Registrar, Technical College, Sunderland, Co. Durham. Applications should reach the undersigned as soon as possible.

Canvassing will disqualify.

W. Thompson,
Director of Education.

Education Offices,
15 John Street,
Sunderland.